July 17, 1934. | H. C. HAYES | 1,966,446

IMPACT TOOL

Filed Feb. 14, 1933 | 2 Sheets-Sheet 1

FIG. 1

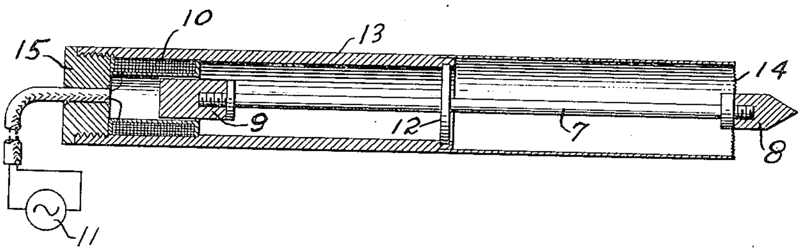

FIG. 2

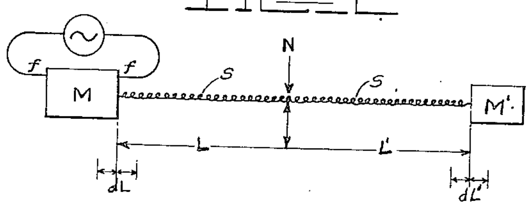

FIG. 3

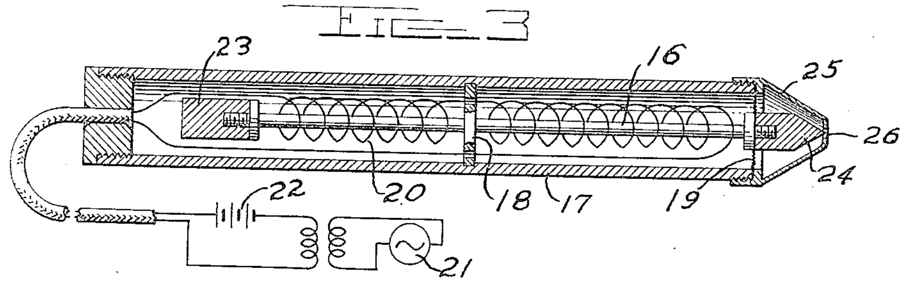

FIG. 4

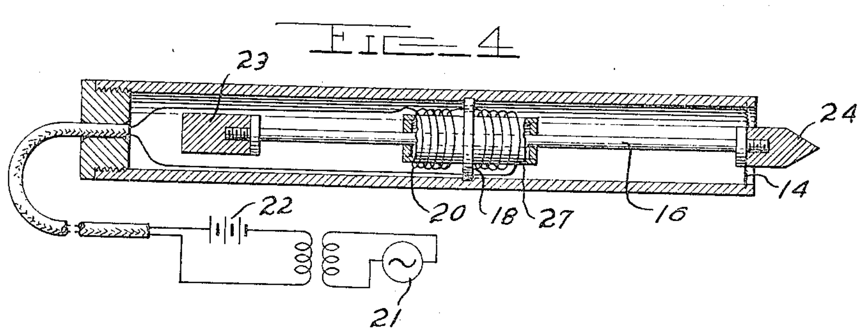

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FIG. 5

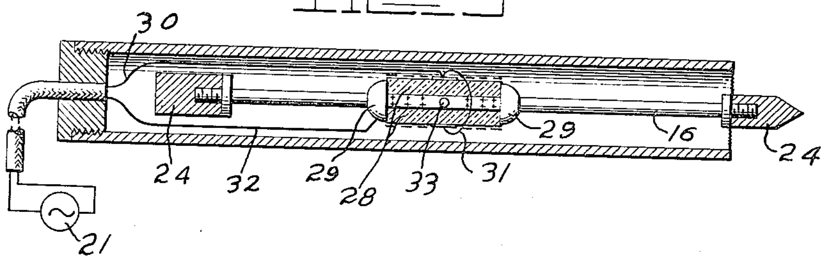
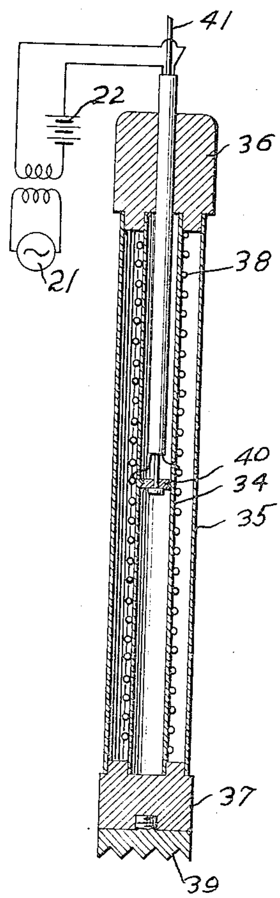


FIG. 6



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UNITED STATES PATENT OFFICE

1,966,446

IMPACT TOOL

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Application February 14, 1933, Serial No. 656,759

21 Claims. (Cl. 172—126)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to actuating means for impact tools.

An object of this invention is to transform electrical energy into vibratory mechanical energy more efficiently than has been done by tools heretofore used.

Another object is to provide impact tools that will do more accurate work than prior devices of this type.

A further object is to reduce to a minimum the irritating effect of such devices upon persons in the vicinity of their operation by causing the blows to be delivered at a frequency above the range of irritability through either touch or hearing.

With the above and other objects in view, this invention consists in the construction, combination and arrangement of parts as will be described more fully hereinafter.

In the drawings:

Fig. 1 shows a form of my invention having a solenoid disposed about a magnetically permeable member that forms part of a vibratory system whereof the working head is another part;

Fig. 2 shows schematically the principle upon which this invention operates;

Fig. 3 illustrates a system wherein the connecting means between two masses is of magneto-strictive material;

Fig. 4 shows a further modification in which the magneto-strictive material is a centrally disposed cylindrical member;

In Fig. 5 the vibratory driving member is a piezo-electric system;

Fig. 6 illustrates an adaptation of my invention to a rock drill.

It is well known that periodic stimuli, either visual, tactile or auditory, cause fatigue and nervous strain if the frequency thereof lies within the rather definite range of 1 to 15 or 20 per second. Below the lower limit, no conscious effort is required to differentiate and separate successive stimuli from one another and above the range mentioned the rapid persistence of excitation blends them all together into a continuum and there is no tendency to segregate individual impulses. However, excitations at frequencies in the range mentioned above evoke a more or less conscious and continuous effort to distinguish the successive impulses, which results in nervous strain.

A examples of this phenomenon there are cited the following: The pile driver, which delivers blows at relatively long intervals and causes no particular discomfort; the riveting hammer has a period within the range mentioned above and has a distinctly disagreeable effect upon persons within hearing range thereof; the impulses from a fog signal form such a continuous flow of energy as to cause no irritation. If a succession of blows having a frequency of more than one per second and less than 20 per second are struck against a tooth, the sensation is very unpleasant but if the frequency is made greater than the maximum of that range, they give the impression of a continuous pressure against the tooth, which is much less trying.

Whether the impact tool is designed to compress and head a rivet, or to form and pack a tooth filling, or to chip away the material being worked upon, the tool must do a certain amount of work and since time is a direct factor in such operations, the rate at which the work is done must be considered in designing the apparatus. Since the desired effect is attained by hammer blows, the rate of doing work can be computed by multiplying the work per blow by the rate at which the blows are delivered, i. e., the same amount of work can be accomplished by heavy blows applied at relatively long intervals or by lighter blows delivered more frequently. Therefore, if the impacts are made to occur at an unusually high frequency, the energy in each impact need not be great to achieve the same time rate of doing work and the nervous effect upon a person in the vicinity will be proportionately less. Thus, when high frequencies are employed as the activating source, not only is the irritability diminished by operating above the sensitive range but also the intensity of stimulation is reduced and at the same time the work is accomplished as rapidly as with the previously known devices.

There are also various mechanical advantages resulting from the use of the present invention as, for example, when applied to a riveting hammer. The rivet head is stronger because the distortion per blow is less and also the shank of the rivet is expanded to fill the hole more compactly than when the work is done by heavy blows.

In Fig. 1 is shown a device that embodies the principles of my invention. A metal rod 7 carries at one end a chisel or other working head 8 and on its other end is mounted a magnetically permeable member 9 which is adapted to lie partially within the solenoid 10 connected to a source 11 of alternating current. A flange 12 secured to rod 7 intermediate its ends is fixed in a housing 13 and serves as the main support of the rod therein. A diaphragm 14 or other suitable flexible mounting is connected to the rod 7 adjacent the working head to center the rod in the housing and to permit of vibratory movements of the rod. A threaded plug 15 closes the other end of housing 13 and locks solenoid 10 in position therein. The flange 12 should be located at the nodal point of rod 7 to prevent interference with the vibration of the rod by the flange. When the magnetic field within solenoid 10 is caused to vary at the same frequency as the resonant frequency of vibration of the system consisting of members 7, 8 and 9, the reaction between the energized solenoid and member 9 of high magnetic permeability will set rod 7 into vigorous longitudinal vibration which will be imparted to the working head 8.

For purposes of mathematical analysis the essential parts of my invention are shown schematically in Fig. 2, wherein the masses and restoring forces are separated and concentrated. Here M represents the effective mass of member 9 and that portion of rod 7 that lies on the left-hand side of flange 12, while M' represents the mass of member 8 and the right-hand portion of rod 7, which may or may not be of the same magnitude as M. The restoring forces are represented by springs SS which are assumed to be without mass and which introduce the same restoring forces when stretched or compressed as does member 7 when stretched or compressed a like amount. The alternating push-pull forces f are assumed equal to the corresponding forces exerted by the solenoid 10 in Fig. 1.

The conditions for resonance are given when the frequency n of the alternating forces f is numerically equal to:

$$n=\frac{1}{2\pi}\sqrt{\frac{F}{M}}$$

where F is the force required to stretch the length L of spring S one unit of length. Since N represents the node, it must follow that

$$n=\frac{1}{2\pi}\sqrt{\frac{F}{M'}}.$$

Moreover, since the coefficient of elasticity of the spring is equal to that of rod 7, Fig. 1, it follows that

$$n=\frac{1}{2\pi}\sqrt{\frac{YA}{ML}}=\frac{1}{2\pi}\sqrt{\frac{YA}{M'L'}},$$

where Y is Young's modulus for the rod and A is the cross sectional area thereof, since both ends execute the same number of vibrations per second. Thus the location of the node N will be such as to satisfy the relation ML=M'L' and the ratio of the amplitude of oscillation of the two ends will be inverse to the ratio of the two masses. That is, if dL represents the total movement of the free end of mass M and dL' represents the movement of the free end of mass M', we have the relation

$$\frac{dL}{dL'}=\frac{M'}{M}$$

and therefore

$$dL'=\frac{M}{M'}dL.$$

Thus the amplitude through which the tool 8 works will be equal to the amplitude of mass 9 multiplied by the ratio of mass 9 to mass 8. It is apparent that the amplitude of the working head can be made larger or smaller than the amplitude of the driving member and that the mechanical advantage of the device can be adapted to different conditions of service.

It will be noted that the frequency of vibration n depends only on the cross sectional area A of member 7, the value of Young's modulus Y of the material, the length of the member and the effective masses M and M' concentrated at the ends. The frequency of blows delivered by a device of this kind may be easily computed by assuming member 7 to be a bar or tube of uniform cross section with tips of the same approximate weight per unit length as the member 7. Under these conditions the node will lie midway between the two ends and the part of member 7 on each side of supporting flange 12 will vibrate as a half wave length. The frequency will then be equal to the velocity of sound in the material of the rod divided by twice its length, which for such metals as steel, nickel and their alloys is about 16,000 feet per second. If member 7 were six inches long, its resonant frequency would be about 16,000 and it would therefore strike 16,000 blows per second. If this member were 50 feet long, that is, about the length of a section of drill rod such as is used for sinking oil wells, its resonant frequency would be about 160 and the drill bit would strike the bottom of the hole 160 times per second. The effective mass of such a member 7 when reduced to the analytical form shown in Fig. 2 will make both M and M' equal to each other and each equal to the total mass of the member divided by π. If extra masses are attached to the ends, the resonant frequency will be somewhat lower but will still be far above the range of irritation.

The amplitude of member 7 will build up to the point where the internal losses (frictional or otherwise) in the metal are equal to the rate of supply of energy to the vibrating system. The material of member 7 should therefore have a low loss per stress cycle. Phosphor bronze or nickel steel alloy serve particularly well while most metals serve fairly well. With the solenoid type of drive, as shown in Fig. 1, the back E. M. F. increases as the amplitude builds up quite similarly to the back E. M. F. of an electric motor as its speed of rotation increases. Therefore, the device will require more power when the point 8 is working than when it is not working, the same as does an electric motor. The efficiency of a device can be computed in the same way as is that of an electric motor as such devices are in fact reciprocating electric motors and their efficiency can be made comparatively high.

The work that the tip 8 can do is equal to the energy supplied to it less the internal energy losses. Neglecting such losses, which are relatively small, the work done will approximate the average value of f (the driving force) multiplied by the distance through which this force acts per second, which is equal to the amplitude of oscillation times the frequency. Tests made on bronzes and steels have shown that amplitudes equal to ¼ of 1% of the length of the oscillator are safe from fatigue effects and in fact amplitudes of double this value have been used. If the oscillating member is nickel steel and has an amplitude of ¼ of 1% of its length and if the oscillating member 7 is a uniform bar or tube, the resonant frequency is very nearly

$$n=16000\frac{12}{2L}$$

where L is the length in inches of the oscillator member. The distance in inches that the force f moves per second will be equal to

$$\frac{96000}{L}\times.0025L=20\text{ feet.}$$

This represents also the distance the tool will move per second when it is free, but it will be reduced somewhat when the tool is working.

In Fig. 3 a magneto-strictive rod 16 is mounted in a housing 17 by means of a flange 18 and diaphragm 19. The magnetizing solenoid 20 is disposed around the rod 16, an alternating current being supplied to the coil 20 from a source 21. To prevent reversal of the magnetism, a biasing direct current is sent through coil 20 from battery 22. A mass 23 is fixed to one end of rod 16. The working head 24 is secured to the other end of rod 16 and is supported by diaphragm 19. When used by an inexperienced workman the impact of the tool against the work may drive the tool away from the work and as a result it will not be held a uniform distance from the material being worked on. To prevent this, a spacer guard 25 is disposed around the working head 24; the guard is held upon the material being worked and the working head 24 passes through an aperture 26 in the guard to strike the material.

The form of my invention shown in Fig. 4 is very similar to that of Fig. 3 except that the spacer guard 26 has been omitted and the magneto-strictive material is in the form of a cylindrical member 27 disposed around the nodal portion of rod 16. The corresponding parts in this figure have been given the same reference numerals as in Fig. 3.

A different device for applying the principle of this invention is shown in Fig. 5. Here the rod 16 is caused to vibrate by piezo-electric crystals 28 disposed between collars 29 on rod 16. The faces of the crystals 28 that lie adjacent the rod 16 are of like polarity as indicated on the drawing. The outer faces of crystals 28 are connected to a source 21 of alternating current by wires 30 and 31, the other terminal of source 21 being connected to rod 16 by a wire 32. As in the previously described forms of my invention, the rod 16 is supported at its nodal point by a member 33.

An adaptation of my invention to rock drilling tools is shown in Fig. 6. Two heavy tubes 34 and 35 of magneto-strictive material are mounted concentrically between masses 36 and 37. The energizing coil 38 is wound upon the tube 34 and is connected to a biasing battery 22 and a source 21 of alternating current. The rock bit 39 is detachably secured to the mass 37. The inner tube 34 has fixed to it at its nodal point a diaphragm 40 to which is secured a cable 41 by means of which the device may be raised or lowered in a drill hole. The magneto-strictive vibration of tubes 34 and 35 causes the bit 39 to be driven repeatedly against the rock at the bottom of the drill hole. The device is made of sufficient weight to give the proper working pressure to hold the bit in effective contact with the rock. It can be readily shown mathematically that the energy developed by a device like that of Fig. 6 may be as great as several horsepower and therefore it is apparent that such a tool may serve for drilling oil wells in place of the heavy and expensive rotary drills now used.

Preferably each of these tools will be operated at its mechanical resonance frequency for the reason that at resonance the amplitude of vibration becomes enormously greater than at other frequencies but they will operate at other frequencies, and for some purposes the resulting smaller amplitudes may prove advantageous. However, where riveting or drilling or some other like operation that requires the delivery of sharp blows is undertaken, the longer stroke obtained at resonance is much more effective. When so used the operator presses the tool to the work only to such an extent as to prevent its being thrown off from the resonant frequency and under such conditions the tool point leaves the working surface at each stroke much as does an ordinary riveting hammer.

The source of electrical power preferred for operating these tools is such as can be supplied by so-called power tubes where the frequency of oscillation can be adjusted and maintained at the resonant frequency of the vibrating system. This frequency, always relatively high, may vary from several thousand per second when applied to engraving and dental tools to a few hundred per second in case of drills and powerful riveting outfits. In general the high frequency tools require less power and may be operated by ordinary power tubes such as are employed in connection with radio equipment. The higher power and lower frequency tools, such as rock drills, can best be driven by the modern thyratron type of power tube.

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes, without the payment of any royalty thereon.

I claim:

1. An impact tool, comprising a bar of magneto-strictive material, a working head carried by one end thereof, a counter-balancing mass carried by the other end thereof, said bar and said masses constituting a vibratory assembly, a supporting member secured to said bar at a point thereof which is a node when said bar is in vibration, a housing in which said supporting member is mounted, a diaphragm secured to said housing and to said working head, a spacer guide secured to said housing around said working head, said guide having in it an aperture through which the tip of said head may be projected, a coil disposed around said bar, a source of direct current connected to said coil to impart thereto a magnetic bias and a source of alternating current operatively connected to superimpose an alternating current upon said direct current in said coil.

2. An impact tool, comprising an elastic bar, a working head carried by one end of said bar, a counterbalancing mass carried by the other end of said bar, a cylindrical magneto-strictive member disposed around and connected to said bar intermediate its ends, a supporting member connected to said bar at a point which is a node when said bar and said masses are in longitudinal vibration, a housing disposed around said bar and in which said supporting member is mounted, a diaphragm connected to said housing and to said working head, a coil disposed around said cylindrical member, a source of direct current connected to said coil and a source of alternating current operatively connected to superimpose an alternating current upon said direct current through said coil.

3. An impact tool, comprising an elastic bar, spaced collars on said bar, a plurality of piezo-electric crystals mounted between said collars with faces of like polarity against said bar, a source of alternating current, means connecting one terminal of said source to said bar, other means connecting the other terminal of said source to faces of said crystals not in contact with said bar and having like polarity, a working

head carried by one end of said bar, a counter-balancing mass carried by the other end of said bar, a housing member disposed around said bar, means to support said bar within said housing, said last mentioned means being connected to said bar at a point which is a node when said bar is in longitudinal vibration and a diaphragm connected to said working head and said housing.

4. An impact tool, comprising a bar of magneto-strictive material, a working head carried by one end of said bar for impacting a body to be worked upon, a counterbalancing mass carried by the other end of said bar, means to support said bar at a point which is a node when said bar is in longitudinal vibration, a coil disposed around said bar, means to impress a fluctuating voltage on said coil and means to support said working head to permit longitudinal movement thereof but prevent lateral movement thereof.

5. An impact tool, comprising a working head for impacting a body to be worked upon, a counterbalancing mass spaced therefrom, means connecting said working head and said mass including a magneto-strictive element, means to support said connecting means at a point which is a node when the aforesaid parts are in longitudinal vibration, means to subject said magneto-strictive element to a fluctuating magnetic field and means to support said working head to permit longitudinal vibration thereof but prevent lateral movement thereof.

6. An impact tool, comprising a working head for impacting a body to be worked upon, a counter-balancing mass, a magneto-strictive element operatively connected to said working head and said mass, means to subject said element to a steady magnetic field, other means to impress thereon a fluctuating magnetic field and means to support said working head to permit longitudinal vibration thereof but prevent lateral movement thereof.

7. An impact tool, comprising a working head, a counter-balancing mass, an elastic member connecting said working head and said mass, piezo-electric elements connected to said member to cause said member to vibrate longitudinally, means to impress a fluctuating voltage upon said piezo-electric means, means to support said elastic member at a point which is a node when said member is in longitudinal vibration and means to support said working head to permit longitudinal vibration thereof but prevent lateral movement thereof.

8. An impact tool, comprising a working head for impacting a body to be worked upon, a counter-balancing mass spaced therefrom and operatively connected thereto and magneto-strictive means to cause said working head and said mass to vibrate as a unitary system.

9. An impact tool, comprising a working head for impacting a body to be worked upon, a counter-balancing mass spaced therefrom and connected thereto, electrically actuated means to cause said working head and said mass to vibrate as a unitary system and supporting means for all the aforesaid elements disposed at a point which is a node when such system is in vibration.

10. In an impact tool, a vibratory system comprising a working head and a counterbalancing mass, and means to set said system into vibration parallel to the line joining said head and said mass at frequencies greater than 15 per second.

11. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, and magnetostrictive means adapted to set said system into vibration.

12. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, and electrically excited vibratory means to set said system into vibration parallel to the line joining said head and said mass.

13. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, supporting means for said system connected thereto at a nodal point therein and electrically actuated means to set said system into vibration parallel to the line joining said head and said mass.

14. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, supporting means for said system connected thereto at a nodal point therein and magneto-strictive means to set said system into vibration.

15. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, supporting means for said system connected thereto at a nodal point therein, supporting means connected to said working head to permit longitudinal vibration thereof but to restrain said head from lateral movement and electrically actuated means to set said system into vibration.

16. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass, and magnetostrictive means to set said system into vibration, said system having sufficient weight to hold the working head in operative contact with the material being worked upon when used in position such that the said weight is applied to said head.

17. In an impact tool, an elastically vibratory system comprising a working head for impacting a body to be worked upon and a counterbalancing mass and electrically actuated means to set said system into vibration parallel to the line joining said head and said mass.

18. In an impact tool, a vibratory system comprising a work head for impacting a body to be worked upon, a mass spaced therefrom, and an elastic member connecting said mass and said head; and means to set said system into vibration, the distribution of mass in said system being such that said system is adapted to vibrate in a single wave.

19. In an impact tool, a vibratory system comprising a working head for impacting a body to be worked upon, a mass spaced therefrom, and an elastic member connecting said mass and said head; means to set said system into vibration, the distribution of mass in said system being such that said system is adapted to vibrate in a single wave and supporting means for said system connected to said system at the intermediate node of said wave.

20. In an impact tool, a first mass including a working head for impacting a body to be worked upon, a second mass, an elastic member connecting said masses, means to apply to the system comprising said masses and said elastic member periodic forces of a frequency equal to the resonant frequency of said system and mounting

means for said system secured thereto at a nodal point.

21. In an impact tool, a vibratory system comprising two masses and an elastic member connecting said masses, one of said masses including a working head for impacting a body to be worked upon and each of said masses being disposed at a loop of a vibrational wave in said system, supporting means for said system at a node of a vibrational wave in said system and means to cause said system to vibrate at its resonant frequency.

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