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| Continuation-in-part of application Ser. No.
695,745, Jan. 4, 1968, now Patent No.
3,527,501. This application Jan. 26, 1970,
Ser. No. 5,448 | | |

- [50] **Field of Search**..... 173/49;
299/14, 37; 172/40; 37/DIG. 18; 175/56

[56] **References Cited**

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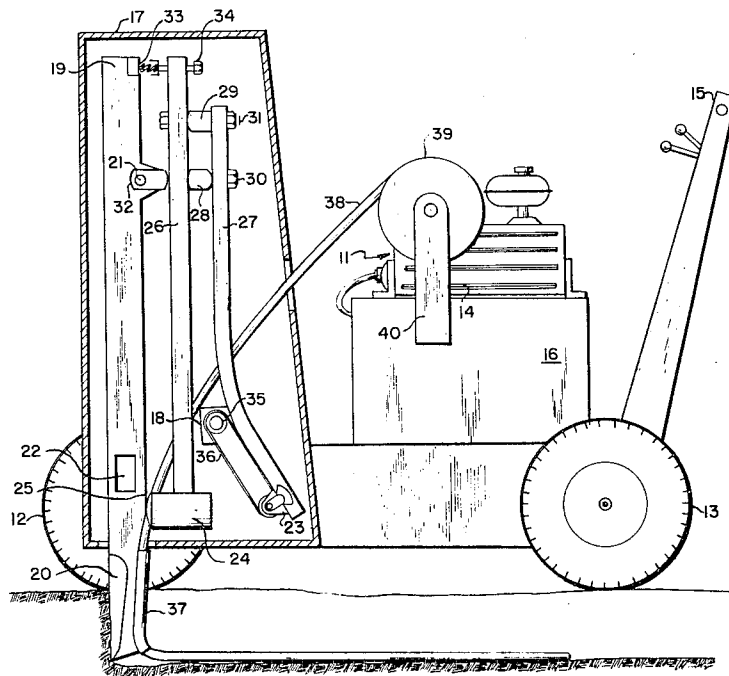
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[54] **NONLINEAR RESONANT VIBRATORY WORK SYSTEM**

6 Claims, 4 Drawing Figs.

- [52] U.S. Cl..... 173/49,
61/72.6, 172/40, 299/14
- [51] Int. Cl..... A01b 35/00
B06b 1/16

ABSTRACT: A resonant vibratory system utilizes nonlinear elastic transmission means to operatively connect an oscillator to a work member to provide a nonsinusoidal vibratory system having a high-velocity work stroke and a low-velocity return stroke for greatly reducing draft or propulsive load on a work member. The oscillator is coupled to the transmission means so as to be isolated from high-velocity impulses delivered to the work member.



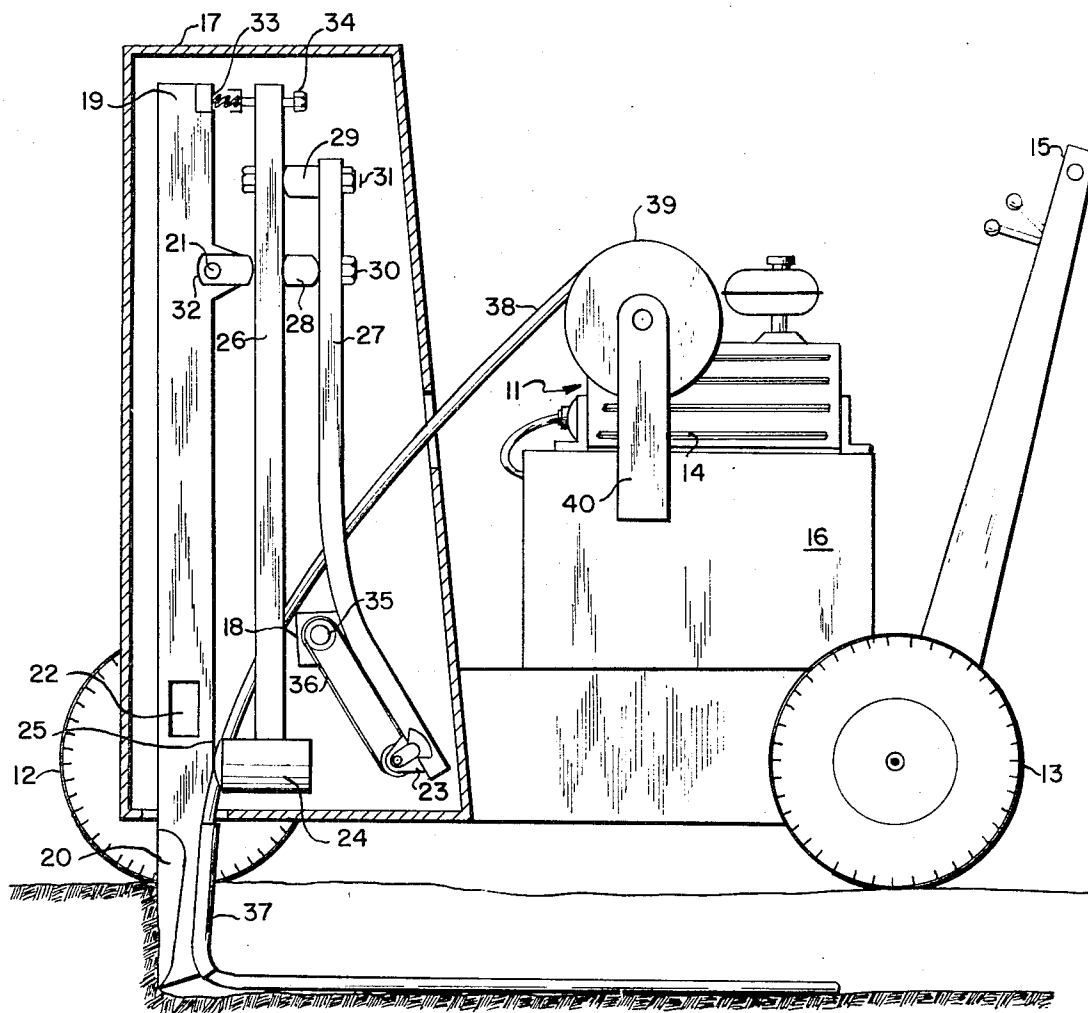


FIG. 1

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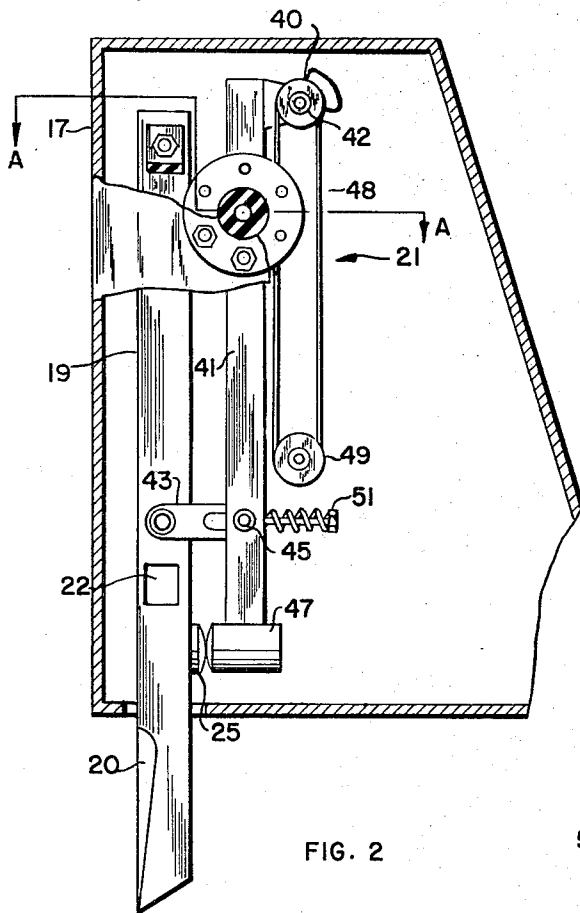


FIG. 2

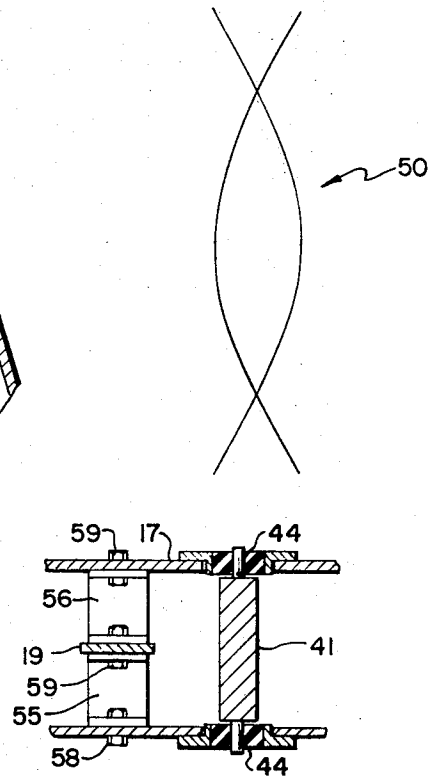


FIG. 2a

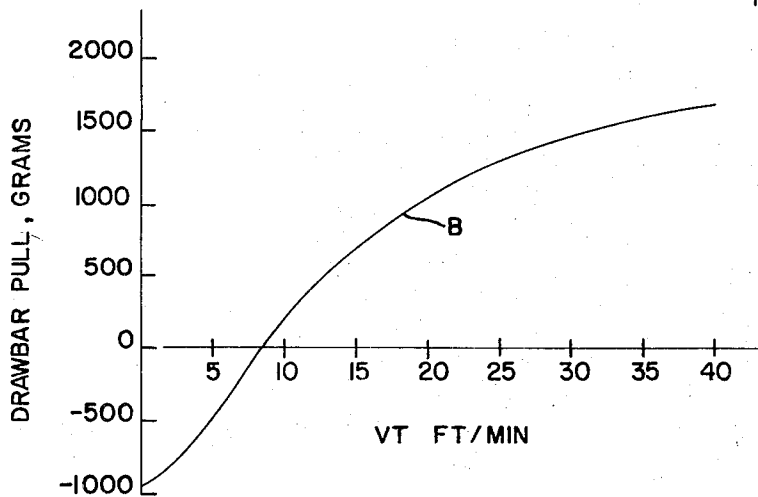


FIG. 3

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NONLINEAR RESONANT VIBRATORY WORK SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of my copending application Ser. No. 695,745, filed Jan. 4, 1968 and now U.S. Pat. No. 3,527,501.

BACKGROUND OF THE INVENTION

This invention relates to cable plows and pertains more particularly to a nonlinear vibratory cable plow that is essentially self-propulsive.

Sonic tools have recently achieved a wide range of industrial uses. These sonic tools typically employ an elastic resonant member coupled between an oscillator and a tool or work member such that when operated in its resonant mode the tool will be at a velocity antinode and undergoes a cyclic stroke movement against the work. Typical of such tools are sonic polishers, sonic scrapers, sonic cutters, sonic plows, etc. Typically these tools go through a work stroke and a return stroke. The return stroke of such tools, in most cases is a waste of motion and in many cases results in a waste of energy. The waste of energy occurs particularly in situations where it is necessary to overcome friction on the return stroke. One example of such loss is on the return stroke in the cable plow or sonic trenching tool. In the use of a sonic trenching tool the trench is cut on the forward stroke of the cutting blade while on the return stroke the sides of the blade are in frictional engagement with the sidewalls of the trench. An analysis of the conditions and forces involved in sonic trench-forming indicates that the major forces are those resulting from coulomb friction which is independent of the velocity of the tool. There is very little, if any, viscous damping found under such conditions. This indicates that the damping force on the cutting blade is independent of the velocity of the blade. Further analysis reveals that it is desirable to make the cutting stroke as rapidly as possible in order to minimize the retarding impulse on the vehicle and then to urge the blade toward the rear for a longer time but with a lower force, preferably less than the available side friction force in order to reduce the power loss of retrograde motion but still to provide a maximum propulsive impulse to the vehicle. Prior known sonic cutting tools are constructed to have symmetrical stroke and thus, do not take advantage of the above knowledge. Therefore, such devices unnecessarily waste considerable amounts of energy.

In my aforementioned application there is disclosed apparatus for overcoming the above disadvantage of the prior art devices. However, one disadvantage of the aforementioned apparatus is that the life of the oscillator is reduced by the high-impact loads upon it.

SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to overcome the aforementioned disadvantages of the prior invention devices by providing apparatus having high-force capability, high-velocity work stroke and a longer duration lower force urging the blade toward the rear, wherein the oscillator is isolated from the shock of the energy delivery stroke.

It is a further object of the present invention to limit or minimize the energy dissipated by sonic tools on its nonwork stroke by providing sonic tools with a reduced force urging the tool toward a return stroke.

A further object of the present invention is to provide means for reducing the draft or propulsive load on a sonic tool.

A still further object of the present invention is to provide cutting apparatus that takes advantage of side friction in a cut to provide a propulsive impulse to the apparatus.

The above and other objects of the present invention are obtained by providing a sonic resonant system with elastic resonant energy transmitting means having nonlinear response characteristics which combine with nonlinear or friction load conditions to give a high acceleration, high velocity, short du-

ration impulse on the forward or work stroke and a lower force long duration impulse on the return stroke, wherein the oscillator is isolated from the high acceleration impulses.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation with portions cut away, of a sonic trench forming tool embodying the principles of the present invention;

FIG. 2 is an illustration of an alternate embodiment of the present invention;

FIG. 2a is a sectional view essentially along lines A—A of FIG. 2;

FIG. 3 is a plot of drawbar pull versus forward velocity, a trenching tool constructed in accordance with principles of the present invention.

Referring now to the drawings and more particularly to FIG. 1 there is illustrated a cable laying machine incorporating a preferred embodiment of the present invention. The illustrated machine is a small version, and includes a suitable transport or traction vehicle 11 having front wheels 12 and rear wheels 13. The vehicle 11 is preferably propelled and the systems powered by a suitable prime mover such as a gasoline engine 14. Suitable controls for the various systems of the machine are located such as on a control panel 15 for easy access by an operator. Suitable transmission and hydraulic systems, not shown, may be obtained in an enclosure 16.

The trench forming apparatus may be contained in a suitable housing means 17 which is preferably pivotally supported such as at 18 on vehicle 11. This pivot 18 should pivot the blade down into the ground near the rear of the vehicle and up out of the ground in front without getting the blade depth too great in the process. This arrangement permits pivoting the housing toward the rear of the vehicle with suitable power means, not shown, and withdrawing the trenching blade from the formation.

The trench forming apparatus comprises an elongated work member 19 having a trench forming or earth cutting portion 20, which in its normal working position is substantially vertically oriented and adapted for a work path transverse to its axis. The member 19 is compliantly mounted in housing 17 to isolate shock generated from the housing. This is accomplished for example by providing a pivotal connection 21 of member 19 to housing 17 near the upper end and a mount 22 having resilience such as by being partially constructed of rubber so as to permit a slight amount of movement (1 inch or so as bias is applied) of member 20 about pivot 21.

The blade 20 is propelled or activated primarily by a nonlinear vibratory or energy delivery system. The primary propelling system may be of any suitable form adapted to apply short duration high force to the blade 20 along the direction of the work path and a long duration low force thereto in the reverse direction. Such a propelling system will make the blade 20 essentially self-propelling provided the forward force is sufficient to overcome the resistance of the formation (coulomb friction) and the reverse force is generally less than that required to overcome side friction (back reaction) imposed on blade 20 by the sides of the trench. In this manner the primary propelling system utilizes the back reaction of the blade 20 acting against the sides of the trench as reaction means against which to work to store impulse for the forward stroke. For this reason the blade is provided with a suitable amount of frictional area for engagement with formation (sidewalls of the trench) to provide the necessary back reaction for impulse storage during the back stroke of the primary propelling system. It is essential that the vibratory or energy delivery system be tied such as by elastic means to the blade to generate this back reaction to provide a propelling impulse.

The primary blade propelling means of the FIG. 1 embodiment comprises a vibratory system. This vibratory system may preferably be a resonant system in order to achieve greater efficiency in the use of oscillator force and to permit isolation of

the oscillator from the impact of the hammer blows. In the illustrated embodiment, an oscillator 23 is coupled by elastic transmission means to the work member 19. The transmission means comprises a hammer 24 supported to intermittently strike the work member 19 at a suitable place such as an anvil 25. The hammer 24 is supported for oscillations by means of an elastic member 26 which is connected to a second elastic member 27 to which is coupled the oscillator 23. The bars 26 and 27 are coupled together in the form of a tuning fork such as by means of spacers 28 and 29 and suitable clamps or bolts 30 and 31, and coupled to work member 19 by means of a suitable clamp or bolt and a spacer 32 containing the blade pivot. A suitable coupling spring 33 having means such as a bolt 34 to adjust the compression therein is provided to maintain coupling of the hammer 24 with the work member 19. The arrangement of elastic members 26 and 27 clamped together at the top as shown form essentially a tuning fork with leg 27 isolating the oscillator 23 from the shock of the impacts of hammer 26 against the anvil 25 on work member 19. The leg or elastic member 27 is curved to permit the use of a pulley 35 coaxial with trunnion 18 and positioned between members 26 and 27 to be used to supply power by means of pulley 36 to the oscillator 23. The coupling spring 33 is to assure that the transmission means are so coupled that the hammer 24 will impact against the anvil 25 during each oscillation of the hammer and that a rearward or back reaction force will be exerted on the blade by the movement about pivot 21 as spring 33 is compressed during the time the hammer 24 is away from contact with anvil 25.

The system is preferably provided with suitable means for laying a cable as the trench is formed. This may be achieved by forming a suitable conduit 37 in blade 20 through which a cable 38 is directed to the bottom of the trench from a spool 39 supported such as by means of bracket 40 on vehicle 11.

FIG. 2 illustrates a second embodiment of the apparatus of FIG. 1 with an alternate form of transmission means. As illustrated, a work member 19 is supported as in FIG. 1 in housing 17 or alternately such as by means of rubber or elastomer blocks 55 and 56 bolted at 57 to blade 19 and at 58 and 59 to housing 17. The housing 17 is supported such as for example as in the previous example from vehicle 11. A transmission means comprising an elongated elastic member 41 operatively couples an oscillator 42 to work member 19. The elastic member 41 is supported such as by complaint mount 44 at its upper node and supports a hammer 47 which impacts against anvil 25. The oscillator 42 is driven such as by a belt 48 and pulley 49 powered by suitable prime mover means. The oscillator 42 is isolated from the shock of impacts of hammer 47 by means of its position of attachment the elastic member 41. Suitable coupling spring 51 is preferably provided to maintain hammer 47 coupled in proper relation to anvil 25 so that the hammer strikes a blow during each oscillation along the path of travel of the trenching tool 20. Alternatively a tension spring (not shown) can be used to tie the hammer 47 to the anvil 25 or the function of the coupling spring can, to whatever extent desired, be combined with that of the bias spring 22 by providing compression springs behind the hammer and in front of the blade both bearing on the housing. In operation, the oscillator 42 sets the elastic bar 41 in motion, preferably in a lateral resonant mode as indicated by wave pattern 50. This motion causes hammer 47 to swing alternately toward and away from anvil 25 and delivering an intermittent impact

thereto along the path of travel.

The above-described operating characteristics of the FIG. 1 embodiment of the present invention produce some dramatic results that are illustrated in FIG. 3. The plot in FIG. 3 also illustrates the results of changing the parameters of the components that go to make up this system. In the graph of FIG. 3 is plotted the velocity of the towing vehicle versus drawbar pull for a scale test model constructed in accordance with the principles of the present invention. Line A on this chart indicates the drawbar pull of the model without vibration of the blade. This is also called the dead blade pull. Plot B illustrates the typical performance of the model with vibration. It is to be noted that this plot extends through the zero draw pull point to the negative side at low forward velocities. This plot shows that quite a substantial forward speed can be maintained with these tools without any drawbar at all, that is, when completely disconnected from any towing vehicle. Moreover they can even push against any retarding force to the extent of one-half or so of the value of dead blade pull before being forced to a complete stall of forward speed. Looking at plot B, for example, at drawbar pull of zero, the forward velocity is about 8 feet per minute. Furthermore, if it is required to push forward against a retarding drawbar force of approximately 400 grams on the scale, it is still able to propel itself forward at a velocity of about 5 feet per minute.

I claim as my invention:

1. A nonlinear resonant vibratory work system, said system comprising:

an oscillator;

an elongated work member, said work member being supported for a work stroke in a given direction transverse to the longitudinal axis thereof;

an elastic energy transmission means operatively connecting said oscillator to said work member and operative to transmit oscillatory forces to said work member substantially parallel to said work stroke path;

said transmission means including impacting means comprising a hammer for intermittently delivering an impact to said work member along the direction of said work stroke; and

an elastic bar coupling said oscillator to said impacting means to isolate said oscillator from the shock of said impacting means, said bar carrying said hammer at one end and said oscillator at the other.

2. Claim 1 wherein said hammer comprises a mass supported substantially on the end of an elongated member; said elongated member being pivotally supported adjacent to said work member and extending substantially parallel thereto.

3. Claim 2 including spring means for coupling said hammer to said work member.

4. Claim 1 wherein said transmission means includes a tuning fork for coupling said oscillator to said hammer, one leg of said tuning fork supporting said hammer and, the other of said legs supporting said oscillator.

5. Claim 1 wherein said transmission means includes a first elongated member supporting said hammer adjacent said work; and,

a second elongated member coupled to said first member and supporting said oscillator.

6. Claim 1 including coupling spring coupling said hammer to said work member.

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