

Aug. 20, 1957

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2,803,433

TORSIONALLY OSCILLATING OIL WELL DRIVE BIT

Filed March 8, 1952

2 Sheets-Sheet 1

FIG. 1

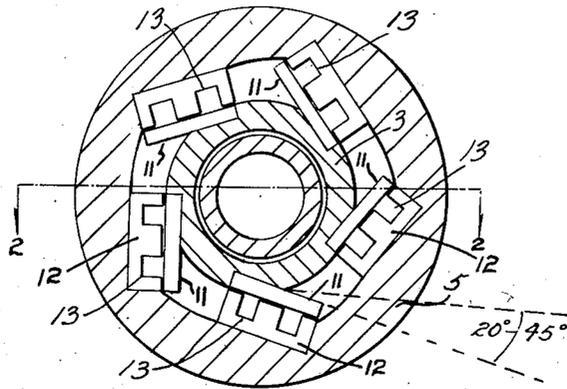
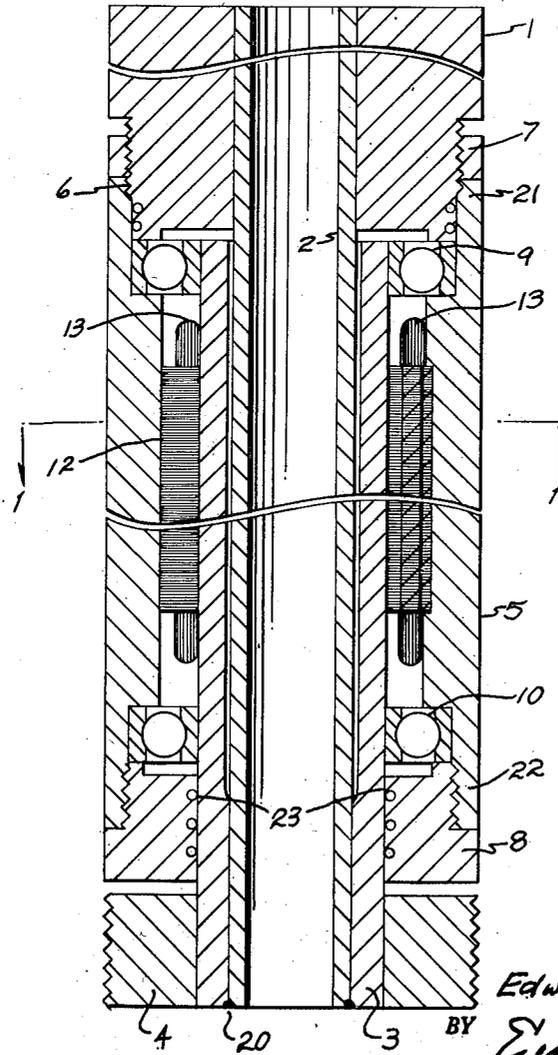


FIG. 2



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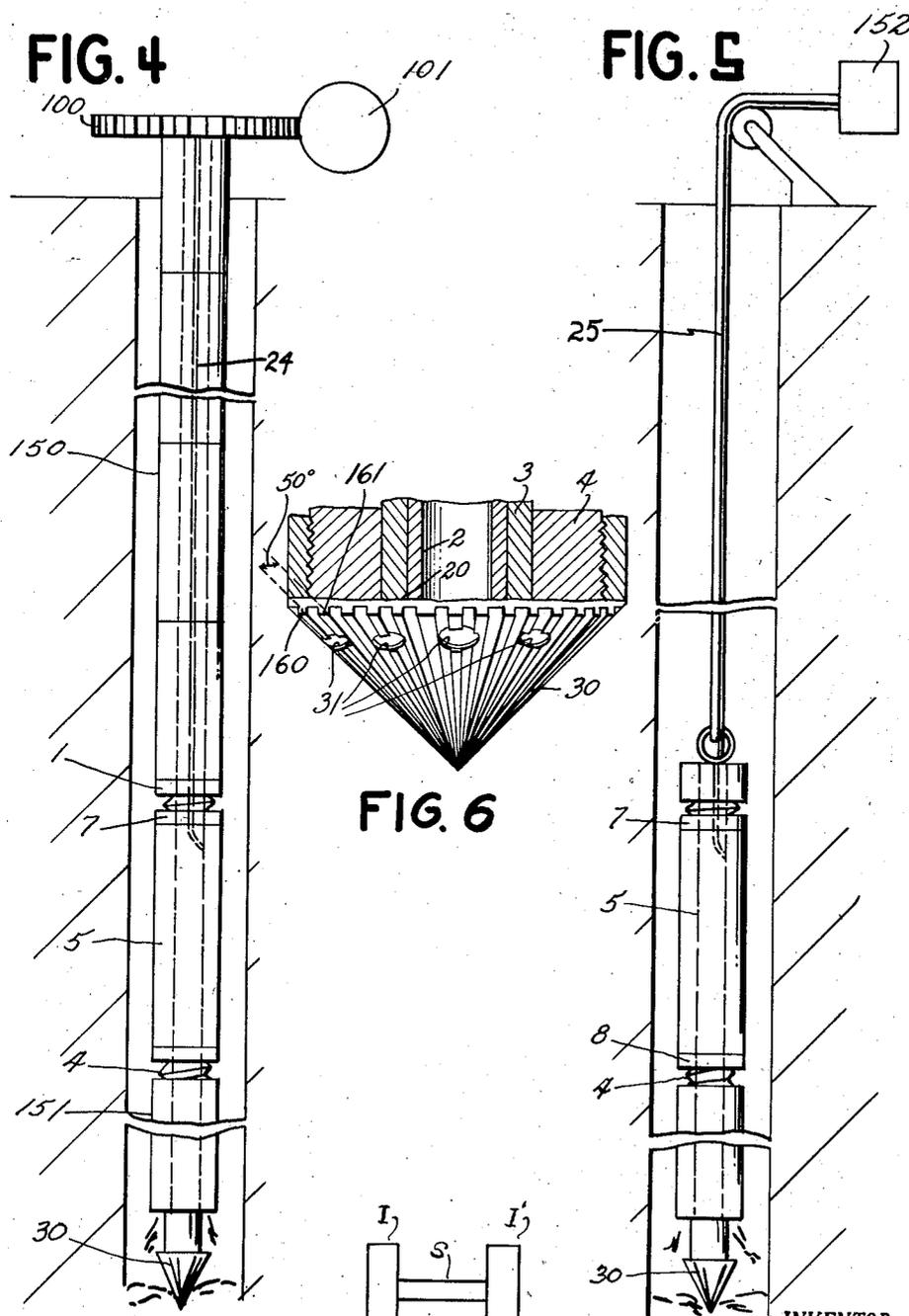


FIG. 3

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TORSIONALLY OSCILLATING OIL WELL
DRIVE BIT

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16 Claims. (Cl. 255—1.8)

The present invention relates to oil well drilling and in particular relates to means and methods of torsionally vibrating or oscillating the drill about its drilling axis independent of or simultaneously with the rotation of the drill or bit. In general there are two methods of oil well drilling to which the present invention applies. One, the rotary drill, and second, the cable tool drilling when the tool is made to impact against the spot to be drilled.

In the conventional rotary oil well drill, the power to rotate the bit is delivered from the surface by means of a sectional drill pipe made up to the length required as the drill descends and is rotated by coupling the drill pipe through a speed reducer to a suitable source of power such as a gas engine.

In the conventional rotary drill equipment mentioned above, a considerable loss of power results from friction of the drill pipe against the side of the hole, etc., so that in order to have a given amount of power available at the bit, an enormously greater amount of power must be supplied to the top end of the drill pipe. Unsuccessful attempts to overcome these difficulties have been heretofore made, but these have failed, because of excessive drill wear, complicated power supply requirements, difficulties in operating rotating equipment in oil wells except by the use of the customary drill pipe, and so forth.

Another and not inconsiderable drawback to the use of the conventional rotary drilling equipment is the cost and quantities of high grade steel required for the drill pipe.

One of the objects of the present invention is to provide a torsionally oscillating drive for an oil well drill of the rotary and non-rotary types.

Another object of the invention is to provide a drive which will deliver its power output directly to the drill and thus eliminate, or substantially reduce the amount of expensive drill pipe required as well as reducing the wear on it and the friction losses normally encountered. This is accomplished because the rotary drive power, on account of the shaft oscillations may be applied on the lower section of the drive shaft.

In connection with this object of the invention, it should be observed that the torque required at the bit for effective drilling must be transmitted from the surface as previously set forth. A substantial portion of this energy is lost in friction against the sides of the hole, thereby requiring that a substantially greater amount of torque be delivered at the top of the unit than is actually derived as a useful output at the lower end. For this reason in conventional rigs, it is necessary to provide a very high grade and expensive alloyed steel for the drill pipe in order to transmit the required torques. In the present invention, however, due to the torsionally oscillating system, the energy required to transmit the requisite amount of power to the bit does not have to be delivered through the drill pipe but can be delivered electrically. The other function of the drill pipe, that is delivering drilling mud to the bit, can be accomplished with a much less expen-

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sive tube made of a cheaper grade of steel which does have to withstand any substantial torques.

Still another object of the invention is to provide the oscillating power in such a way as to not interfere with the normal delivery of drilling mud to the tool by sending it through a hollow center shaft structure. In connection with this object of the invention it is to be noted that the means for providing oscillating power to the cutting tool does not interfere with the passage of drilling mud through the drilled hole. Conventional means (not shown) may, therefore, be used to deliver mud to the drilled hole during the drilling process.

The method and means whereby the above objects as well as others are accomplished may best be understood from the following specification set forth below when taken in connection with the drawing illustrating embodiments of the invention, in which:

Figure 1 shows a cross section through the drill shaft section embodying my invention on the line 1—1 of Figure 2.

Figure 2 shows a vertical section on the line 2—2 of Figure 1.

Figure 3 shows diagrammatically the torsional system.

Figure 4 shows somewhat diagrammatically a section through a well being drilled, showing a complete drilling unit according to the present invention.

Figure 5 shows a modification of the view shown in Figure 4.

Figure 6 shows a detail of a drilling tool such as may be used at the end of a drill shaft.

Assuming for the moment that we have two masses having inertias I and I' connected by an element having torsional stiffness, such as a rod or tube. Such a system has a natural period of vibration which is dependent upon the magnitude of the two inertias I and I' , and the torsional stiffness of the connecting element S supporting the masses having the inertias I and I' .

With such a system, if a periodic torsional acceleration having a frequency corresponding to that of the natural period of oscillation of the system shown in Figure 3 is applied, then the inertias of the two separate masses will cause oscillations torsionally about their common axis but in opposite directions.

Furthermore it will be apparent that under such conditions the opposite ends of the element S to which the two inertia members are secured, must likewise be moving in opposite directions so that obviously there is a point somewhere inbetween where no motion of element S occurs. This point may be referred to as the nodal point and its distance from the two inertia members is inversely proportional to their respective magnitudes. In other words, the nodal point is further from the smaller of the two inertia members. In exactly the same way the angular amplitude of the two inertia members is inversely proportional to their magnitudes, i. e. the larger inertia member moves at the smaller amplitude. The oscillation amplitude of the drive shaft is governed by these proportions and dimensions.

It may also be stated that the larger inertia member is at the shortest distance from the nodal point and the smaller inertia member is farthest from the nodal point. This physical fact and the determination of the nodal point is helpful in designing the invention for a particular application. Principally it is helpful to know the location of the nodal point for applying the present invention to a rotary rig, for it is desirable to attach the unit to the rig at the nodal point where movement due to the torsional oscillation is at a minimum.

With the above facts in mind, consideration may now be given to the detailed construction of the driving mechanism which is one of the objects of the present invention.

Referring first to Figure 2, it will be noted that an

inertia element 1 is solidly secured by shrink fitting or other suitable means to a tubular element 2, the opposite end of which is secured by welding 20 or other suitable means to a concentric and larger diameter tube 3, their common contact region being secured by shrink fitting to collar 4. It will further be noted that an outer casing 5 is solidly secured at one end to inertia element 1 by means of threads 6 on the outer side of cylindrical element 1 and inner side of outer casing flange 21, and lock nut 7 and is likewise solidly secured at its other end by means of interengaging threads on flange 22 of casing 5 and on the outside of collar 8 surrounding tube 3 but free to move angularly with respect to tube 3 about their common axis, for the purpose of which packing O rings 23 are used to bear against the outside of tube 3. It will further be noted that two bearings 9 and 10 are provided to accurately align tube 3 concentrically with outer casing 5.

In the above described arrangement of elements we have a torsionally resonant system consisting of the inertia element 1, and the inertia of casing 5 and collar 8 solidly secured at one end of or elastic member or a tube 2 having torsional stiffness, the other end of which is solidly secured to another inertia element consisting of tube 3 and collar 4 plus whatever may be secured to collar in the way of a tool. The rotational force applied at the top of the shaft through the inertia mass 1, the tube 2, the inertia masses 3 and 4 and the mass of the tool is periodically opposed by the magnetic forces across 11 and 12 to set up a torsional resonance.

It will be apparent then, that if a torsional acceleration is suddenly applied between the two inertia elements just described, the ends of the torsion tube 2 will be twisted in opposite directions, and at a frequency determined by their magnitude and the torsional stiffness of tube 2. Furthermore, if the torsional acceleration is applied periodically at the same frequency as the natural period of vibration of the system, the angular amplitude of oscillation may be made any desired value within the physical limitations of the material of tube 2.

The means whereby a torque can be most conveniently applied between the ends of the torque tube 2, can best be understood from an examination of Figure 1, showing a section 1—1 through the elevation shown in Figure 2. In Figure 1, it will be noted that a series of plate-shaped armature elements 11 made up of flat lamination are disposed around the drive shaft or tube 3 and rigidly secured to the tube 3, and that the inner edges of the armature laminations make an angle greater than zero degrees but less than 90° with the perpendicular to the radius line of the tube 3 drawn where the plates 11 intersect the outer surface of tube 3. As indicated in Figure 1, this may be and preferably is somewhere from 20° to 45°. It will further be noted that a series of E-shaped stator elements 12 are disposed around the inner circumference of casing 5 and secured to the casing in such a way that the faces of the legs of the E-shaped laminations 12 are substantially parallel to and separated slightly from the slat-shaped armature elements.

If now the coils 13 surrounding the middle leg of the E-shaped stator blocks are energized, a magnetic flux is set up between the armature and stator elements and consequently a pull is exerted between them. In addition, due to the angular manner in which they are disposed relative to the radius, there is a component of this pull which tends to rotate tube 3 with respect to tube 5 and as a consequence the ends of the torsion tube 2 are twisted in opposite directions. This twisting effects a storage of energy in the tube 2, which is released when the current in the coil 13, is interrupted or goes through its node in the alternating cycle.

When the energization is removed the potential energy resident in the twisted torque tube will be released and the tube 3 and collar 4 will move angularly relative to the casing 5. If now the coil is energized with alternat-

ing current of one half the frequency of the natural period of vibration of the system, collar 4 and tube 3 will oscillate torsionally about their common axis and in opposite direction at all times to the similar motion of casing 5 and inertia element 1.

It will be clear that if a cutting tool is secured to collar 4, then it likewise will oscillate while being rotated, about the axis of the system and at an angular amplitude which is determined by the amount of current passed through winding 13.

Furthermore, if the angular motion of the cutting tool is made somewhat greater than the pitch of the cutting edges of the tool, it will not be necessary to rotate the unit during operation. Pitch is defined as the angular distance between the cutting edges, such as 160 and 161, of the tool. Referring to Figure 6, if the cutting tool 30 has a pitch of 5°, then if the amplitude of oscillation of the cutting tool is more than 5°, the cutting tool will, in its oscillation, continue to rotate in the same direction and produce a regular cut. The cutting tool 30 is attached to the piece 4 by suitable means, such as collar 151; and it may have holes 31 through it to allow for the passage of drilling mud and around the end of the tool.

As will already have been noted the above described driving or oscillating power unit, has a hollow tubular core through which drilling mud may be passed in the conventional manner. The unit or structural section shown in Figures 1 and 2 may as shown in Figure 4 be secured in the usual way to the end of an ordinary string of drill pipe, or may even be attached to the end of a length of hose of proper construction to support its weight and provide a passage for the downward movement of the circulating drill mud. A two conductor cable 24, see Figure 4, passing down the hole may serve to carry the necessary electric power to the unit. The casing 5, in Figure 4, may be constructed as in Figure 2, to establish an oscillatory resonance. The rest of the structure comprises tube sections connected to casing 5 to which the tool is attached. The elements 100 and 101 are respectively a worm gear and worm suitably connected to the drill pipe 150 for rotating it. At the lower end of the drill pipe 150 there is connected the casing 5 through the cylindrical member 1 and lock nut 7. At the lower end of the unit the cutting tool 30 is attached by suitable means as set forth above.

Although reference has been made up to now to the application of the unit to operations where a rotary drill would normally be used, it may be applied with equal facility to operations where cable tool drilling would normally be used. In this latter case the drilling may be by impact of raising and lowering the tool, or by a rotational drive, or by a progressive oscillatory movement of the resonant unit which causes a rotation of the drill shaft. In this instance the unit would be suspended by a cable 25, Figure 5, carrying the electrical conductors mentioned above and during operation the unit may be raised and lowered occasionally from conventional means 152 to stir up the mud pool at the bottom of the hole and keep the chips of drilled material in suspension until they can be bailed out in the usual way. An obvious advantage in this case is that such raising and lowering need only be occasional, and for the purpose of stirring the mud so that the cable is not subjected to the strains to which it usually is in ordinary cable drilling operations.

In the design of such a unit as has been described above, reference has already been made to the fact that in such a system as this, the two inertias oscillate in opposite directions, i. e. 180° out of phase. It is equally true that their respective amplitudes of torsional oscillation are inversely proportional to the magnitude of their respective inertias. Consequently, if we make the inertia of element 1 and its associated casing 5 and the collar 8, large with respect to the inertia of the other end of

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the system consisting of tube 3 and collar 4 plus the inertia of whatever may be secured to the collar in the way of a tool, the motion of this end of the system will be large compared to the motion of inertia element 1 and its associated casing 5. This is a distinct advantage because under such conditions the amplitude of motion of inertia element 1 is practically zero although the amplitude of motion at the cutting end may be substantial. By designing the equipment in this way, strains on the means used to support the unit are likewise eliminated, as little, if any of the vibrational energy is transmitted to the supporting means.

Although the above described driving unit may be designed for any desired frequency of torsional oscillation and angular amplitude, it will probably be found convenient to design it for a frequency of 120 cycles per second because 60 cycle alternating current needed to operate such a unit at this frequency is almost universally available.

In designing such a unit the maximum torque required to give the necessary maximum acceleration to the masses of the moving parts may be obtained from the relationship.

$$\text{Torque} = 12J_m a \omega^2$$

(See page 96, of the Engineers Manual, by Ralph G. Hudson, published by John Wiley Company, (second edition).)

where torque is the torque required in inch pounds, J_m is the mass moment of inertia in pound feet squared, ω is 2π times the frequency in cycles per second and α is the angular amplitude of motion desired in radians.

Having established the value of torque required the torsion tube 2 may be designed so that the above value of torque will be required to twist it through the desired angular amplitude.

It will be clear that under such conditions as above described the potential energy resident in the twisted torque tube at the end of the stroke is available to start the moving parts backward again in the opposite direction so that this energy is then converted into kinetic energy in the moving parts and back again into potential energy in the twisted shaft at the opposite end of the stroke. In effect it gives a flywheel action to assist the motion of the cutting element to and fro.

As has been stated above, if the pitch of the cutting edge of the tool is less than the angular motion of oscillation of the cutting tool due to the torsional movement, then drilling may be accomplished without the rotation of the shaft. This is extremely important in deep drilling since the shaft is usually rotated from the top of the drill hole. Under these conditions the drill shaft may simply serve to provide the necessary pressure and if rotated, the rotation may be at a very slow speed. With an 8" diameter drill it is possible to obtain the circumferential amplitude of approximately $\frac{1}{4}$ " which is the equivalent of approximately 2.7° . The energy in such a case is supplied by cable to the lower section of the drill which thereby eliminates the twisting of a very long shaft which is obviously objectionable for a great many reasons.

As this invention relates to a means and method of torsionally vibrating or oscillating the drill about its drilling axis independent of or simultaneously with the rotation of the drill or bit, no attempt has been made to disclose the precise means for effecting continuous rotation of the drill nor has any means been shown for effecting the supply of drilling mud to the drilling hole. It should be understood, however, that the well-known conventional means for accomplishing these functions may be used in connection with the continuous rotation of the drill about its drilling axis. A conventional worm and worm gear arrangement, as is schematically represented in Figure 4, may be used.

Having now described my invention, I claim:

1. A method of oil well drilling which comprises establishing in a drill shaft a torsionally oscillatory system with a mass secured at each end of an elastic torque tube

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element coaxial with and forming a part of the drill shaft and electrically applying torsional accelerations periodically to said masses of a frequency equal to the natural frequency of torsional vibration of said system between the ends of the tube element to establish a resonant oscillation in which the masses oscillate angularly in opposite directions to one another about the tube as an axis with interchange of kinetic energy in the masses to potential energy in the stiffness of the torque tube element.

2. A method of oil well drilling which comprises applying torsional accelerations of a frequency equal to the natural frequency of torsional vibration of the system in opposite directions to longitudinally spaced portions of a lower section of a drill shaft in the vicinity of an attached drill periodically to establish a resonant oscillation in said section in which opposite ends of the section oscillate angularly in opposite directions to one another about the section as an axis.

3. A method of oil well drilling which comprises forming a lower section of a drill shaft as a torsional resonant system adapted to oscillate about the axis of the shaft with each end of said section oscillating angularly in opposite directions to each other and loading said section with desired masses at each end for establishing the desired relative amplitude of oscillation between the ends of the shaft of a frequency equal to the natural frequency of torsional vibration of said system.

4. Means for torsionally oscillating a drilling bit comprising a cylindrical torque tube, means providing a driving connection from the torque tube to the drilling bit, electromagnetic driving means in two independent parts, a pair of tubes coaxial with said torque tube each one of said pair of tubes carrying one of said independent parts with one of said pair of tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, said electromagnetic driving means being positioned to provide a force component perpendicular to the radius of said torque tube at its circumference.

5. Means for torsionally oscillating a drilling bit comprising a torque tube, means providing a driving connection from the torque tube to the drilling bit, two tubes coaxial with said torque tube one about the other and both about the torque tube, one of said two tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, and means for applying electrical forces between said two tubes adapted to be periodically energized and when energized having force components perpendicular to the torque tube at the ends of the radius of said torque tube.

6. Means for torsionally oscillating a drilling bit comprising a torque tube, means providing a driving connection from the torque tube to the drilling bit, two tubes coaxial with said torque tube one about the other and both about the torque tube, one of said two tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, and electromagnetic means between said two tubes and connected thereto adapted to be periodically energized and when energized having force components perpendicular to the torque tube at the ends of the radius of said torque tube.

7. Means for torsionally oscillating a drilling bit comprising a torque tube, means providing a driving connection from the torque tube to the drilling bit, two tubes coaxial with said torque tube one about the other and both about the torque tube, one of said two tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, and electromagnetic means between said two tubes and connected thereto, adapted to be periodically energized, and when energized having force components perpendicular to the torque tube at the ends of the radius of said torque tube, comprising sets of elongated armature blocks attached on the outer face of the inner of the two coaxial

tubes and a set of corresponding energizing electromagnets attached to the inner face of the outer of said coaxial tubes.

8. Means for torsionally oscillating a drilling bit comprising a torque tube means providing a driving connection from the torque tube to the drilling bit, two tubes coaxial with said torque tube one about the other and both about the torque tube, one of said two tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, and electromagnetic means between said two tubes and connected thereto, adapted to be periodically energized, and when energized having force components perpendicular to the torque tube at the ends of the radius of said torque tube, comprising sets of elongated blocks of armatures and electromagnets attached to the outer face of the inner of said coaxial tubes and the inner face of the outer of said coaxial tubes in opposing relation one to the other.

9. Means for torsionally operating a drilling bit comprising a torque tube means providing a driving connection from the torque tube to the drilling bit, two tubes coaxial with said torque tube one about the other and both about the torque tube, one of said two tubes firmly attached to one end of said torque tube and the other firmly attached to the other end of said torque tube, and electromagnetic means between said two tubes and connected thereto, adapted to be periodically energized, and when energized having force components perpendicular to the torque tube at the ends of the radius of said torque tube, comprising sets of elongated armature blocks attached on the outer face of the inner of the two coaxial tubes and a set of corresponding energizing electromagnets attached to the inner face of the outer of said coaxial tubes, the outer faces of said armatures and electromagnets being set at an angle substantially larger than 0° but less than 45° with the tangent to the radius at the contact of said armatures with the said inner coaxial tube.

10. A method of oil well drilling which comprises applying a torsional oscillation to a drill shaft adjacent a cutting tool having spaced cutting edges and having an amplitude greater than the pitch of the cutting edge of the cutting tool.

11. A method of oil well drilling which comprises

simultaneously rotating a drill shaft and applying torsional oscillation thereto about the axis of the drill shaft in a section of the drill adjacent the cutting tool.

12. A method of oil well drilling which comprises applying a torsional oscillation to a drill shaft in a lower section thereof, said drill shaft having attached thereto a cutting tool with spaced cutting edges said torsional oscillation having an angular amplitude greater than the pitch of the cutting edge of the tool and simultaneously longitudinally reciprocally moving the drill shaft.

13. A method of oil well drilling which comprises applying a torsional oscillation to a drill shaft in a lower section thereof, said drill shaft having attached thereto a cutting tool with spaced cutting edges said torsional oscillation having an angular amplitude greater than the pitch of the cutting edge of the tool and simultaneously intermittently, longitudinally, reciprocally moving the drill shaft.

14. Means for torsionally oscillating a drill bit comprising a drive shaft for rotating the drill bit, means for torsionally oscillating the drive shaft including means providing masses coupled by an elastic member and means for providing periodic torsional elastic forces for oscillating said elastic member.

15. Means for torsionally oscillating a drill bit comprising a drive shaft therefor, means for torsionally oscillating said drive shaft comprising means for applying torsional forces between sections of said drive shaft to provide periodic twists of the shaft between the ends of said sections in opposite angular directions.

16. Means for torsionally operating a drill bit comprising a drive shaft for rotating the drill bit, means for torsionally oscillating the drive shaft including means providing masses coupled by an elastic member and means for providing periodic torsional elastic forces for oscillating said elastic member, said forces being applied at resonance of the system including the drive shaft and the masses operating the torsional forces.

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