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VIBRATORY TYPE APPARATUS FOR USE IN ROTARY DRILLING OF BOREHOLES

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FIG. 1

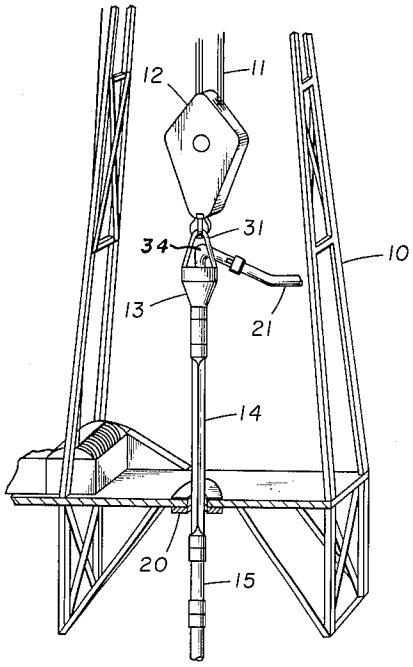


FIG. 2

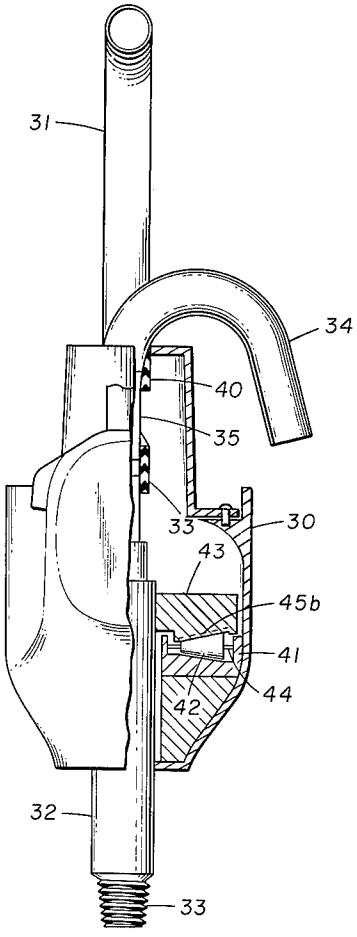
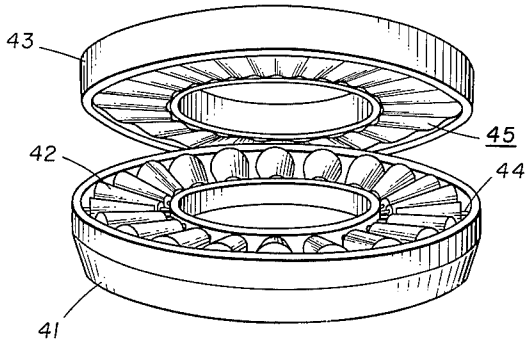


FIG. 3



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FIG. 4

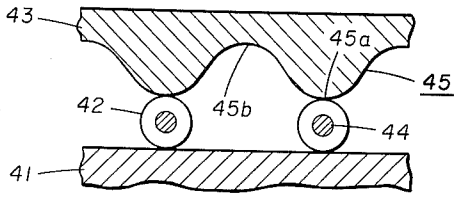


FIG. 5

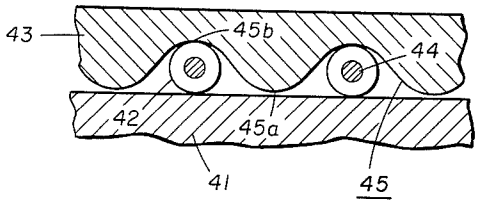


FIG. 6

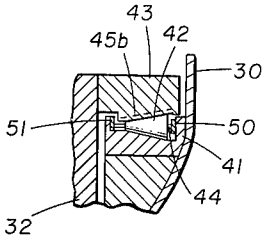
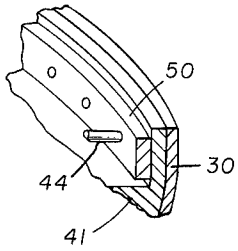


FIG. 7



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United States Patent Office 3,235,014 Patented Feb. 15, 1966

3,235,014

VIBRATORY TYPE APPARATUS FOR USE IN ROTARY DRILLING OF BOREHOLES

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Filed July 1, 1963, Ser. No. 291,971
5 Claims. (Cl. 173—57)

This invention relates to apparatus for drilling boreholes in earth formations. More specifically, this invention relates to surface-mounted, vibratory type apparatus which may be used with conventional rotary equipment for the drilling of boreholes in earth formations.

Methods and apparatus have been suggested for generating vibratory energy at the surface and applying such energy to the upper end of a drill string in carrying out conventional rotary drilling of boreholes. The apparatus which has been suggested, however, represents a substantial departure from that which is normally employed in rotary drilling. For this reason, the operation and maintenance of such equipment may require the use of personnel and other services not normally necessary in conventional rotary drilling.

It is an object of the present invention to provide apparatus for applying vibratory energy to the surface end of a drill string. It is another object of the invention to provide vibratory type drilling apparatus which represents a minimum departure from presently known rotary drilling elements while improving the drilling action at the bottom of the borehole. It is a still further object of the invention to provide a novel form of swivel which combines vibratory energy-generating features with the conventional functions of a swivel in rotary drilling.

In accordance with the invention, a substantially conventional form of rotary swivel is adapted to deliver vibratory energy to the upper end of a drill string by means of an improvement which includes supporting the stem of the swivel on a cam surface cooperating with the main thrust bearings to cause the stem to reciprocate as it is turned by the rotary table.

In the drawings:

FIGURE 1 is a plan view in perspective of a portion of the general combination of elements employed in conventional rotary drilling;

FIGURE 2 is a view partially in elevation and partially in section of a swivel constructed in accordance with the invention;

FIGURE 3 is a perspective view in elevation of the main thrust bearing elements of the swivel of FIGURE 2;

FIGURE 4 is a fragmentary view in section of the main bearing of the swivel of the invention at one stage in its vibratory action;

FIGURE 5 is also a fragmentary view in section similar to FIGURE 4 illustrating a subsequent stage in the vibratory action;

FIGURE 6 is a fragmentary view in section of a modified embodiment of the apparatus of FIGURE 2; and

FIGURE 7 is a fragmentary view in elevation of the embodiment of the apparatus illustrated in FIGURE 6.

FIGURE 1 shows a portion of the general combination of equipment normally required in the rotary drilling of a borehole in an earth formation. Derrick **10** may be any one of numerous types of fixed or portable towers. Suspended over pulleys, not shown, positioned at the upper end or top of derrick **10** are a plurality of cables **11** which support traveling block **12**. Suspended from the traveling block is a swivel **13**, to the lower end of which is secured kelly **14** which supports drill string **15**. Kelly **14** is square or hexagonal in cross section over a substantial portion of its length and fits in sliding relation through rotary table **20** situated in the floor of derrick **10**. The

rotary table, which is actuated by power elements, not shown, serves to turn the kelly, rotating the drill string. Due to the sliding fit between the kelly and the rotary table, as drilling progresses the kelly is allowed to slide downwardly through the rotary table. While the power for rotating the kelly and thus the drill string is applied to the rotary table, the entire weight of the kelly and drill string is supported by swivel **13** which also functions to conduct drilling fluid to the kelly and drill string. Drilling fluid passes through hose **21** into the swivel. As drilling progresses and when it is necessary to add another section of drilling pipe to the drill string, the traveling block, swivel, and kelly are raised and lowered as needed by manipulation of cables **11**.

The essence of the invention resides in the employment of a novel form of swivel **13** which causes the kelly, as it is turned by the rotary table, to be vibrated longitudinally. Thus, there is provided combined rotary and vibratory drilling action.

The invention resides in the swivel illustrated in detail in FIGURES 2–7. Referring specifically to FIGURE 2, swivel **13** includes a housing **30** to which is secured a bail **31** by which the swivel is supported from traveling block **12** as shown in FIGURE 1. Swivel **13** is, in most respects, conventional in design, varying substantially however at the point of the invention. Rotatably positioned within housing **30** and projecting through the lower end of the housing is stem **32** which is threaded at **33** to receive kelly **14** or a coupling which may in turn be connected to the kelly. The stem functions as the sole longitudinal support for the kelly and drill string and as a conduit for directing drilling fluid into the kelly. The upper end of stem **32** forms a fluidtight slip fit with packing **33** which is supported in the housing by any satisfactory means. Connected into the upper end of housing **30** is gooseneck **34** which conducts drilling fluid from a pump, not shown, through the hose **21** into the swivel. Within the housing between the lower end of gooseneck **34** and the upper end of stem **32** is wash pipe **35** which provides the fluid connection between the lower end of the gooseneck and the upper end of the stem. Fluidtight integrity is provided around the connecting point of the wash pipe and the gooseneck by packing **40** which is supported in the housing by any desirable means. The lower end of wash pipe **35** and the upper end of stem **32** are spaced apart a sufficient distance to permit the stem to freely vibrate longitudinally during its rotation. The distance the wash pipe and stem are spaced apart depends upon the amplitude of vibrations for which the swivel is designed. This distance should be at least greater than the maximum amplitude to eliminate interference between the wash pipe and the upper end of the stem.

Stem **32** is rotatably supported within housing **30** by a main thrust bearing which comprises the combination of bottom race **41**, a plurality of bearings **42**, and thrust block **43**. Bottom race **41** is secured in any satisfactory manner within the housing around stem **32**. In the embodiment of the invention illustrated in FIGURES 2 and 3, each of the bearings **42** is supported on a shaft **44** which is secured at each end into bottom race **41**. Since each of the bearings in this embodiment is mounted in a rotatable but yet fixed position with respect to the bottom race, it will be obvious that each of the bearings will turn but will not travel along the surface of the bottom race. The main portion of the load impressed upon each of the bearings preferably is taken by the shaft since allowing all of the load on each bearing to be impressed upon the bottom race might result in undue wear of the race. Since each of the bearings in this embodiment is maintained in a nontraveling position relative to the race, any contact between the race and the bearings will be a sliding rather than a rolling contact. To prevent exces-

sive impact loads upon each of the shafts, it is preferred that the bearing load be divided between the shafts and the surface of bottom race 41 by allowing some contact between the bearings and the surface of the bottom race.

Thrust block 43 may be constructed integral with stem 32 or, preferably, is formed as a separate part and secured on the stem in any satisfactory manner. The thrust block, in accordance with the invention, functions to provide the sole longitudinal or vertical support for the stem, kelly, and drill string and, further, provides the desired longitudinal vibratory action to the drill string. In accordance with the invention, the lower surface of thrust block 43 is a cammed surface, as may best be observed in FIGURES 3–5. For purposes of reference, the cammed surface of the thrust block shall be referred to as surface 45, having crest portions 45*a* and trough portions 45*b* as seen in FIGURES 4 and 5. Cammed surface 45 may have any configuration necessary to produce the desired vibratory pattern. For example, it may range from a serrated or saw-toothed surface to an undulated surface, as most clearly illustrated in FIGURES 4 and 5. A preferred form of cammed surface 45 is one which will provide the desired vertical vibratory action with a minimum of bearing wear. Such a surface is an undulated one having a sine waveform, as in FIGURES 4 and 5. The amplitude of the vibrations induced in the stem by the cammed thrust block is controlled by the vertical distance between crests 45*a* and troughs 45*b*. The frequency of the vibrations is, of course, related both to the rotary drilling speed employed and the number of crests and troughs provided in the cammed surface of the thrust block. In the embodiment of the invention illustrated in FIGURES 2 and 3 wherein each of the bearings 42 is secured in a fixed position relative to the bottom race, the thrust block will be raised and lowered each revolution the number of times there are troughs and crests in the cammed surface of the block. For example, if there are 10 crests and 10 troughs in cammed surface 45 and the rotary drilling rate is 60 revolutions per minute or 1 revolution per second, the stem and thus the kelly and drill string will be reciprocated by the thrust block ten times each second and, thus, the vibratory cycle will be 10 cycles per second. Obviously, the number of bearings 42 employed is dependent upon the number of troughs and crests provided in the cammed surface. One bearing 42 is required for each crest and trough, as shown in FIGURES 4 and 5. FIGURE 4 represents a stage in the operation cycle when the thrust block is at its uppermost point of longitudinal movement with each of the crests 45*a* of the cammed surface resting upon a bearing 42. FIGURE 5 represents the lowermost point of travel of the thrust block with the center point of each of troughs 45*b* resting upon a bearing 42. As the thrust block is rotated, the cammed surface 45 passes over the bearings 42 which have a rolling contact with the cammed surface, causing the thrust block to be raised and lowered as previously discussed. Thus the cooperative relationship between the cammed surface and the bearings effects the desired vibratory action in the stem, kelly, and drill string.

An alternative form of bearing construction is illustrated in FIGURES 6 and 7. In this embodiment, each of the bearings 42 is supported on a shaft 44 as previously described, with the shaft 44 however being secured to an outer ring 50 and an inner ring 51. Both rings 50 and 51 rest upon bottom race 41 and are so dimensioned that they form a sliding fit with the race to permit them to freely turn within and on the race. The rings 50 and 51, each of shafts 44, and each of the bearings 42 are so dimensioned and positioned that the weight imposed upon the bearings is supported by the upper surface of bottom race 41. This bearing arrangement is to be distinguished from the first-discussed embodiment illustrated in FIGURES 2 and 3 in that the entire load on the bearings is now supported by the upper surface of the bottom race, whereas in the previous embodiment a substantial portion of the bearing load was sustained by the shafts 44. A further distinguishing feature of the present embodiment over that of the previously discussed embodiment is that with the rings 50 and 51 free to turn within the bottom race, the bearings roll along the surface and thus travel with respect to the bottom race. It will be recalled that with respect to the previously discussed embodiment, the bearings do not travel along the surface of the bottom race. Since the bearings 42 have a rolling relationship with the bottom race, the determination of the vibrational frequency of this embodiment varies somewhat from the previously discussed embodiment. The operational frequency of the present embodiment in cycles per second is determined by the expression:

$$f = R(t)\left(\frac{x}{y}\right)$$

where

f is the frequency in cycles per second;
R is the number of revolutions per second made by thrust block 43;
t is the number of crests or troughs in the cammed surface 45;
x is the length of the line of intersection of bottom race 41 with a hypothetical infinitely thin-walled right circular cylinder which has the same vertical axis as the bearing assembly; and
y is the length of the line of intersection of the same hypothetical infinitely thin-walled right circular cylinder with the cammed surface 45.

The reason for the use of the relationship of corresponding circles on the cammed surface and the surface of the bottom race is that while each of the bearings 42 is rolling along the surface of the bottom race, the cammed surface is also rolling on the bearings; and, due to the configuration of the cammed surface, a bearing rolling along any selected segment of the cammed surface and bottom race will be required to roll a greater distance along the irregular cammed surface than along the flat bottom race surface.

While the bearings 42 have been illustrated as tapered roller bearings, it will be evident that other types of bearings, such as ball bearings or straight roller bearings, may be employed. Also, it will be obvious that securing the bearings in place and maintaining their proper spacing may be accomplished in other ways.

It will be apparent to one skilled in the art that any particular design of swivel constructed in accordance with the invention will have a vibratory pattern and frequency range determined in part by the cammed surface on the thrust block. Also, for any particular swivel, the number of vibratory cycles obtainable is directly dependent upon the rotary speed of the kelly and drill string, as controlled by rotary table 20. The number of vibratory cycles of the kelly and drill string is increased and decreased directly with the increase and decrease of the rotary speed of table 20.

Having thus described the apparatus of the invention, it is to be understood that such invention is limited only within the scope of the appended claims.

What is claimed is:

1. In a swivel for use in rotary drilling which includes a housing, a means secured to the housing for suspending the swivel from a traveling block, a means for conducting drilling fluid into the swivel, and a stem rotatably secured within said housing in fluid communication with said drilling fluid conducting means and extending below said housing to support a kelly, the improvement which comprises:

(a) a lower bearing plate secured within said housing around said stem;
(b) a plurality of bearings positioned on said lower bearing plate; and
(c) a thrust block secured to the upper end of said stem and rotatable therewith, relative to said lower

bearing plate, the lower face of said thrust block resting on said bearings to support said stem within said housing, said lower face of said thrust block having a cam surface cooperating with said bearings to cause said stem to reciprocate longitudinally in accordance with the configuration of said cam surface simultaneously with the rotation of said drill stem.

2. The apparatus of claim 1 wherein said plurality of bearings is uniformly spaced around said lower bearing plate and said lower face of said thrust block, in contact with said bearings, has a cam surface comprising a series of alternating uniformly spaced-apart crests and troughs whereby said thrust block, when moving in relation with said bearings, will be caused to uniformly reciprocate simultaneously with the rotation thereof to effect longitudinal vibratory motion in said rotating stem, the frequency and pattern of said rotating motion being in accordance with rotational speed of said thrust block and the configuration of said cam surface.

3. The apparatus of claim 2 wherein said bearings comprise tapered roller bearings.

4. The apparatus of claim 3 wherein each of said bearings is secured to said bottom bearing plate by means of a shaft.

5. The apparatus of claim 3 wherein each of said roller bearings is secured to inner and outer rings supported in sliding relation on said bottom bearing plate whereby said bearings have traveling rolling relationship with said bottom bearing plate.

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