CONSTANT FORCE VARIABLE SPEED VIBRATOR

FIG. 1

FIG. 2

FIG. 3

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This invention relates generally to improvements in vibration producing machines, and more particularly, but not by way of limitation, to an improved vibrator for generating a substantially constant vibrating force at variable frequencies.

In recent developments in the art of seismic exploration for petroleum deposits (U.S. Patent 2,688,124), a vibrating signal having a frequency varying linearly with time is propagated through the earth and is utilized to determine the depth of a potential petroleum deposit. The signal is ordinarily transmitted into the earth by means of a variable frequency vibrator using two counter-rotating eccentric shafts, whereby the force imposed on the earth is imposed in substantially a vertical direction. Each of the eccentric shafts of the vibrator mechanism presently utilizes fixed weights or masses; therefore the force generated by the vibrator increases with increasing speeds of rotation of the shafts. However, it is generally desirable that the force generated by the vibrator be substantially constant over a rather extended frequency range. To accomplish this result, it has been the practice to stop the vibrator between limited frequency ranges for changing the weights on the eccentric shafts. By thus physically changing the weights on the shafts, the force generated by the vibrator can be maintained substantially constant.

However, the vibrator must be stopped frequently and the time involved in both stopping and starting the vibrator, as well as in changing the various weights, is expensive for a commercial operation, and makes the practice of the method inefficient.

It is also known in the art that the increase in the force output of a vibrator may be partially controlled by utilizing an adjustable counter-weight on each eccentric shaft to partially offset the force generated by fixed eccentric weights on the shafts. Prior devices of this nature are usually provided with intricate controlling mechanisms comprising motors and levers to adjust the radii of gyration of the counter-balancing weights at various frequencies of vibration. The position of the counter-balancing weights has also been partially controlled by the use of springs which give way or stretch at increasing speeds of the vibrator. In the spring controlled vibrators, however, the counter-balancing weights are pivotally secured on the eccentric shafts to pivot outwardly from the shaft at increasing speeds of the vibrator. As a result, the rotation of the shaft imposes a force on the counter-balancing weights which is not precisely predictable. That is, rotation of the shaft provides a form of centrifugal force on the counter-balancing weight supporting arms which, to the best of my knowledge, cannot be predicted.

Furthermore, I know of no prior use of a spring system having a variable spring rate for controlling the position of a counter-balancing weight in a vibrating apparatus.

The present invention contemplates a novel vibrator utilizing two counter-rotating shafts, with each of the shafts having a fixed weight eccentrically secured thereon. The centrifugal forces generated by the fixed weights are counterbalanced by smaller weights slidingly secured on the shafts in opposed relation to the fixed, force generating weights. The counter-balancing weights are secured on the shafts to move only in radial directions with respect to the shafts, whereby the reaction of the rotating supporting shafts will not affect the location of the counter-balancing weights by any forces; that is, the weights are not affected by acceleration forces. The position of each counter-balancing weight is controlled only by centrifugal force and a suitable spring system having a variable spring rate, whereby the counter-balancing weights are properly positioned at all times to provide a constant total vibrating force for the vibrator.

An important object of this invention is to generate a constant vibrating force through an extended frequency range, without the necessity of shutting down or physically adjusting the vibrating apparatus during generation of the vibrating forces through the frequency range.

Another object of this invention is to provide a constant force vibrator utilizing a pair of eccentrically weighted shafts having counter-balancing weights, wherein the positions of the counter-balancing weights are not affected by reaction of the supporting shaft. A further object of this invention is to provide a spring controlling system for a constant force vibrator, wherein the spring system has a variable spring rate to precisely position counter-balancing weights of the vibrator and provide a constant force output for the vibrator through an extended frequency range.

Another object is to increase the efficiency of seismic exploration methods utilizing continuous vibrating signals.

A still further object of this invention is to provide a constant force variable speed vibrator which is safe in operation and may be economically manufactured.

Other objects and advantages of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings which illustrate my invention.

In the drawings:

FIGURE 1 is a partially schematic side elevational view of a vibrating apparatus constructed in accordance with my invention.

FIGURE 2 is a sectional view taken along lines 2-2 of FIG. 1.

FIGURE 3 is a sectional view through one of the eccentrically weighted shafts of the vibrator, as taken along lines 3-3 of FIG. 1.

Referring to the drawings in detail, and particularly FIGS. 1 and 2, reference character 4 generally designates a vibrating apparatus which includes a variable prime mover 6 having two forwardly extending parallel shafts 8. The prime mover 6 may be of any suitable size and construction which will provide a counter-rotation of the shafts 8 at variable speeds. That is, the speed of the shafts 8 should be the same at any given instant, but speed of rotation of the shafts may be varied to vary the frequency of vibration of the apparatus 4, as will be more fully hereinafter set forth. The outer end portion of each shaft 8 is journaled in a suitable bearing member 10 extending upwardly from the base 12. The base 12 also supports the prime mover 6.

A force generating weight 14 is rigidly secured on each shaft 8, with the center of gravity of each weight 14 being spaced radially from the axis of rotation of the respective shaft 8, as will be more fully hereinafter set forth.

The weights 14 are secured to the shafts 8 in opposite-hand relation, whereby the centrifugal forces generated by the weights 14 will be additive in a vertical direction, and subtractive in the horizontal directions to provide alternating vertical forces on the base 12.

Each shaft 8 also has a counter-balancing weight 16 slidingly secured thereto on the opposite side of the shaft from the respective force producing weight 14. The weights 16 tend to counter-balance the weights 14, and each weight 16 has a pair of guides 18 (see FIG. 3) thereon in the form of rods to slidingly secure the weights 16 to the shaft 8. Each weight 16 is positioned with respect to its shaft 8 such that the centers of gravity X of the
3 weights 14 and 16 are in line with a diameter D of the shaft 8. Although the uppermost X is described as the center of gravity of the weight 16, it is to be understood that this X actually denotes the center of gravity of the entire counter-balancing system, consisting of the weights 16 and rods 18. The guide rod 18 extend parallel with the diameter D, and each guide rod 18 extends slightly through an aperture or bore 20 formed in the respective weight 14. It will thus be apparent that the bores 20 provide guide-ways for the guide rods 18 to maintain the center of gravity of the counter-balancing weight 16 in line with the diameter D at all times. A suitable head 22 is formed on the outer end of each guide rod 18, and a counter-bore 24 is formed in each weight 14 concentric with the bores 20 to receive a compression spring 26. Each spring 26 is anchored to the inner end of the respective counter-bore 24 and the respective guide rod head 22. It will thus be apparent that the springs 26 constantly urge the weights 16 toward the respective shafts 8 against the centrifugal force generated by each weight 16 during rotation of the shafts 8.

In operation, and as previously indicated, the shafts 8 are rotated in opposite directions to provide simultaneous and opposite rotation of the weights 14. Gyration of the weights 14 will, of course, impose centrifugal forces on the shafts 8, which forces will be transmitted through the prime mover 6 and the bearing member 10 to the common base 12 and produce an output for the apparatus 4 which is a composite of the forces generated on both of the shafts 8. When the weights 14 are being moved generally upward or downward, the weights are moving in the same direction and the centrifugal force generated by each of these weights is added to the centrifugal force generated by the opposite weight to provide a large alternating vertical force on the common base 12 having a frequency corresponding to the speed of rotation of the shafts 8. When the weights 14 are being moved generally horizontally, they are moving in opposite directions; whereby the force imposed on each shaft 8 is cancelled by the force imposed on the other shaft to provide substantially no resultant forces on the apparatus 4 in a horizontal direction.

The force generated by each weight 14 of the vibrator 4 may be determined from the following formula for centrifugal force resulting from rotating an eccentric body about a point:

\[ C = 0.00914 \frac{W R N^2}{g} \]

wherein:
- \( C \) = centrifugal force in pounds,
- \( W \) = weight of the weight 14 in pounds,
- \( R \) = the distance between the center of gravity of the weight 14 and the axis of rotation of the shaft 8, or the radius of gyration of the weight 14,
- \( N \) = revolutions per minute of the shaft 8 and weight 14,
- and
- \( g \) = acceleration due to gravity.

In the present apparatus, however, a counter-balance is used to reduce the centrifugal force imposed on each shaft 8; therefore the expression for centrifugal force on each shaft becomes:

\[ C = 0.00914 \frac{N^2(WR - wr)}{g} \]

wherein:
- \( w \) = the weight in pounds of the counter-balancing weight 16, and
- \( r \) = the distance between the center of gravity of the counter-balancing weight 16 and the axis of rotation of the shaft 8, or the radius of gyration of the counter-balancing weight 16.

In a vibrator constructed according to the present invention, C remains constant for all values of speed \( N \) within a selected speed range. Other constants will be the weight \( W \) of the weight 14, the radius of gyration \( R \) of the weight 14, and the weight \( W \) of the counter-balancing mass 16. When the problem is properly analyzed, it will be apparent that as the speed is varied, it will be necessary to vary the value of \( r \) to give a constant value for \( C \). The value of \( r \) is determined by the springs 26, and this is accomplished through design of the springs, whereby the deflection of the springs is correlated with the desired value of \( r \) at all speeds within the desired speed range. The specific design for each case will be governed by the forces, speeds and space limitations involved, and such a problem, although tedious, is within the skill of the art.

Although I have shown the springs 26 in the form of simple helical springs, it is to be understood that any spring system may be used, providing it possesses a variable spring rate such that the value of \( C \) (in the second formula above) is constant throughout the desired frequency range. For example, the springs 26 may take the form of variable wire sizes, variable mean diameters, nested springs, or a combination of types of springs or hydraulic springs.

In one application of this invention, the required deflection curve for the spring system, which was obtained by plotting deflection (movement of the counter-balancing weight 16) against the load imposed on the system at various degrees of deflection (centrifugal forces generated by the weight 16), could not be met with a single spring within the required force and space limitations. As a result, I used three helical springs in a series and parallel arrangement, the resulting deflection of which closely approximated the required deflection curve. Once the required deflection curve is obtained, the characteristics of the spring system are known, and the system can be readily designed.

From the foregoing it will be apparent that the present invention will increase the efficiency of seismic exploration methods utilizing a continuous vibration signal. The present vibrator generates a constant force through an extended frequency range, without the necessity of stopping the vibrator at any point in the frequency range being transmitted for changing the eccentricity of the force generating weights. The positions of the counter-balancing weights are controlled automatically by a novel spring system having a variable spring rate, such that the centrifugal force imposed on each shaft of the vibrator will be constant at all speeds of rotation of the shaft. It will also be apparent that the apparatus of the present invention may be economically manufactured.

Changes may be made in the combination and arrangement of parts or elements as set forth in the specification and shown in the drawings without departing from the spirit and scope of the invention as defined in the following claims.

I claim:

1. In a vibrator for generating a constant force at variable frequencies, a rotatable shaft, a prime mover, a counter-balance, and a counter-balancing weight, a spring system, a system of guide-ways, a means for driving the shaft at variable speeds, a first weight rigidly secured to the shaft with its center of gravity spaced radially from the axis of rotation of the shaft to impose centrifugal force on the shaft during rotation of the shaft, a second weight slidingly carried by the shaft in a position to partially counter-balance the first weight, said second weight being movable radially with respect to the shaft, and spring means interconnecting the second weight to the shaft for urging the second weight toward the shaft against centrifugal force generated by the second weight, said spring means having a variable spring rate such that the second weight is positioned in accordance with the speed of rotation of the shaft to provide a constant total centrifugal force on the shaft at variable speeds of rotation.

2. In a vibrator for generating a constant force at variable frequencies, a rotatable shaft, a prime mover...
for driving the shaft at variable speeds, a first weight rigidly secured to the shaft with its center of gravity spaced radially from the axis of rotation of the shaft to impose centrifugal force on the shaft during rotation of the shaft, a second weight, means slidingly securing the second weight to the shaft for movement of the second weight only along a radius of the shaft, said second weight being circumferentially spaced from the first weight to partially counter-balance the first weight, a spring system interconnecting the second weight to the shaft for urging the second weight toward the shaft against centrifugal force generated by the second weight, said spring system having a variable spring rate such that the second weight is positioned in accordance with the speed of rotation of the shaft to provide a constant total centrifugal force on the shaft at variable speeds of rotation.

3. In a vibrator for generating a constant force at variable frequencies, a rotatable shaft, a prime mover for driving the shaft at various speeds, a first weight rigidly secured to the shaft with its center of gravity spaced radially from the axis of rotation of the shaft to impose centrifugal force on the shaft during rotation of the shaft, a second weight on the opposite side of the shaft from the first weight, cooperating guides and ways on the shaft and second weight for slidingly securing the second weight to the shaft, said guides and ways being positioned parallel with the diameter of the shaft which extends through the centers of gravity of the first and second weights, and spring means anchored between the shaft and the second weight constantly urging the second weight toward the shaft against centrifugal force generated by the second weight, said spring means having a variable spring rate such that the second weight is positioned in accordance with the speed of rotation of the shaft to provide a constant total centrifugal force on the shaft at variable speeds of rotation.

References Cited in the file of this patent

UNITED STATES PATENTS

1,207,847 Brantingham .......... Dec. 12, 1916
2,171,808 Von Schlippe ............ Sept. 5, 1939
2,286,770 Symons ................ June 16, 1942
2,703,490 Brueggeman et al. ........ Mar. 8, 1955

FOREIGN PATENTS

766,593 Great Britain ............ Jan. 23, 1957
928,917 Germany ................. June 28, 1956
1,106,435 France ................. July 20, 1955