This invention relates to improvements in mining machines of the kind employing a power-rotated digging head with cutting bits mounted thereon, together with an out-of-balance weight rotatably mounted in said head to produce simultaneous rotation and vibratory movement of the head, whereby the digging action of the cutter bits is enhanced.

The invention consists more particularly in improvements in the type of mining machine broadly disclosed in the application of Charles E. Berry, Serial Number 145,468, filed February 4, 1950, and has for its principal object to provide improved supporting means and drive connections for the relatively rotatable digging head and vibrating weight.

A further object of the present invention is to provide improved power-drive connections whereby both the digging head and vibrating weight are rotated from a single drive motor.

A still further object of the invention is to provide improved drive gearing arrangements for producing certain predetermined cutting actions of the cutter bits, depending upon the relative speed and direction of rotation of the digging head and vibrating weight.

Another object of the present invention is to provide a plan view of a mining machine including my improved form of vibratory digging mechanism;

Figure 2 is an enlarged detail view in side elevation of the vibratory digging mechanism shown in Figure 1;

Figure 3 is an enlarged detail section taken on line 3—3 of Figure 1;

Figure 4 is a detail side view of the digging head;

Figure 5 is a section taken on line 5—5 of Figure 3;

Figure 6 is a diagrammatic view showing the drive gearing for the digging head and off-center weight employed in the machine shown in Figures 1 to 5, wherein the digging head and weight are driven in opposite directions to each other;

Figure 7 is an enlarged fragmentary diagrammatic view illustrating the digging action or motion pattern of a cutter bit on the digging head which is driven by the gearing shown in the preceding figures;

Figure 8 is a diagrammatic view showing a modified form of drive gearing for the digging head and off-center weight, wherein the gear ratio is changed so as to modify the motion pattern of the several digging bits;

Figure 9 is a diagrammatic view illustrating a modified digging action or motion pattern of the digging bits resulting from a change in gear ratio as shown in Figure 10;

Figure 10 is a diagrammatic view showing another modified gearing arrangement wherein the digging head and off-center weight are both driven in the same direction and at a different speed ratio;

Figure 11 is a diagrammatic view showing a modified digging action or motion pattern of the digging bits resulting from the gearing arrangement shown in Figure 10.

Referring now to details of the embodiments of my invention and, in particular, to details of construction of the digging head and power drive connections therefor which form the principal features of my present invention, I indicates a frusto-conical rotatable sheath on which are mounted a plurality of bit supports 2, 2 adapted to receive bits or picks 2a in detachable engagement therein projecting from the side walls of said shell. In the form shown herein, the bit supports 2 are arranged in a plurality of rows disposed in generally helical lines from the front to the rear ends of the shell, as shown in Figures 4 and 5. 3 is an off-center weight fixed as by pegging on a front end section 4c of a drive shaft 4. The shell 1 is rotatably mounted on said shaft section 4a by a pair of antifriction ball bearings 5, 5 at the rear end of the shell and an antifriction roller bearing 6 at the front end of the shell.

The rear end of the shell is enclosed by a plate 7 detachably connected about its periphery to the rear end of the shell 1 and having the antifriction bearings 5, 5 supported in an inwardly extending recess 7a at the rear face of said plate. A centrally aperture retaining plate 8 is fixed to the plate 7 for holding antifriction members 5, 5 in recess 7a.

The drive shaft 4 comprises three integral sections, indicated at 4a, 4b and 4c. The rear section 4c constitutes the main bearing support for the shaft and is of substantially larger diameter than the other sections. The intermediate section 4b is disposed on the same axis as the inner section 4c and is somewhat smaller in diameter and of greater length than said inner section.

The front section 4a, on which the off-center weight 3 is fixed and on which also the shell 1 is rotatably supported, as previously mentioned, is axially offset from the intermediate section 4b at a point immediately to the rear of the shell 1.
The common longitudinal axis of the inner section 3c and the intermediate section 4b is indicated in Figure 3 by the line AC, while the length of the shaft of the inner section 3c is indicated at AB, and the length of the intermediate section is indicated at BC. The offset axis of the front section 4a is indicated in this figure at DB in the unperturbed arrangement shown, the axis DE of the front or crank section 4a is substantially parallel to the main rotational axis AC. If desired however, the axis DE, as extended rearwardly, might pass substantially through the point B at the juncture of sections 4c and 4b, so that the angular deviation of axis DE with respect to the main axis AC might be represented by the angle EBC.

The main axis AC, if extended, is arranged to pass substantially through the combined center of gravity of shell 1 and weight 3, for purposes to be hereinafter more fully explained. My improved digging mechanism, including a drive motor 9, is supported on a suitable platform 10 which is bodily adjustable relative to a suitable mobile base 11 for various digging movements, as will hereinafter be more fully described. The digging mechanism and drive means therefore carried on frame 10 comprises the following:

The rear section 4c of main drive shaft 4 is journaled at its rear end in a self-aligning bearing unit 19 mounted in an annular ring 30 fixed in an upright support bracket 21 suitably fixed on the platform 10. This self-aligning bearing unit permits limited orbital oscillatory movements of shaft 4 about the point substantially at A. A pair of retaining plates 22, 22 are fixed to opposite sides of ring 20 and extend inwardly to enclose the bearing unit 19.

A second upright support bracket 23 is suitably fixed on the platform 10 at a substantial distance from the first-named support bracket 21 for supporting the main shaft 4 at the point of juncture B between the rear section 4c and the intermediate section 4b of said main shaft. The bracket 23 has an enlarged annular aperture 24 therethrough having two inwardly stepped shoulders 25 and 26 adjacent the rear of said aperture.

A metal ring 27 has its periphery fitted in engagement with shoulder 26 when a second ring 28 is fitted in spaced relation near the front of the aperture 24. A pair of discs 29 and 30 of yieldable material such as rubber, herein of substantially the same internal and exterior diameter as the ring 27, are secured as by bonding to the opposed inner faces of the rings 27 and 28, respectively. The inner opposed faces of the two yieldable discs 29 and 30 are secured as by bonding to an outwardly extending plate 31 formed integral with a supporting ring 32. A self-aligning bearing unit 33 is mounted in ring 32 which surrounds the front end of the rear shaft section 4c of the main drive shaft 4. In the form shown, the ring 32 has a pair of retaining plates 34, 34 fixed thereto and extending inwardly to enclose the self-aligning bearing 33.

A spacer sleeve 35 is mounted on shaft section 4c with its opposite ends in abutting engagement with the inner faces of the bearing units 19 and 33. The flexible bearing support structure just described is arranged to permit the main shaft 4 to rotate in slightly off-center relation to its normal axis AB under certain conditions since the rubber discs 29 and 30 are arranged to permit limited radial shifting of supporting ring 22 and bearing unit 33 with respect to the supporting bracket 23 in response to rotary or orbital oscillating movements of the shaft produced in response to vibratory action of the off-center weight 3, as will hereinafter be more fully described.

It will be observed that the oscillating movement of the main shaft 4 with respect to the bracket 23 is arrested at point A at the inner end of the shaft 4, where the latter shaft is supported in the self-aligning bearing 19 on the bracket 21.

The shell 1 is driven from motor 9 on platform 10 at a different speed than the weight 3 and shaft 4 through separate power drives such as shown in the form of drive gearing shown in Figures 1 to 3. The drive connections for the shell 1 consist of an internal gear 37 secured to the rear face of the retaining plate 8 and loosely meshed with external teeth 38 formed on the front end of a hollow tubular shaft 39. The latter shaft surrounds the intermediate section 4b of drive shaft 4, in spaced relation thereto. The rear end of the tubular shaft 39 has external teeth 40 loosely meshed with an internal gear 41 fixed as by bolts 42 to the hub of a spur gear 44. The spur gear 44 is mounted on a hollow bearing 46 which surrounds the rear end of the main drive shaft section 4b in spaced relation therewith. The hollow bearing 45 is formed integrally with a supporting plate 46, the outer periphery of which is secured to the front face of the supporting bracket 23 as by bolts 46a. The rear face of the supporting plate 46 also has an inwardly offset annular shoulder 47 fitting within the aperture 24 in the supporting bracket 23 to engage and hold in place ring 25 to which one of the yieldable discs 29 is bonded.

The spur gear 44 is driven through a pinion 48 fixed on the front end of a shaft 49 which extends through and is journaled upon both the supporting bracket 23 and the supporting bracket 21 as by antifriction bearings 50 and 51. A spur gear 52 is fixed on the rear end of the drive shaft 43 and is engaged with the motor pinion 53 of motor 9. The motor pinion 53 is also meshed with a gear 54 on stub shaft 55 which is mounted coaxially with and connected for driving engagement with the rear end of the main shaft rear end section 4c of the main shaft 4. As seen in Figure 3, the stub shaft 55 has its rear end rotatably mounted in antifriction bearing unit 56 supported in a boss 57 fixed in a front face of a supporting plate 58 for the front end of the motor 9. The front end of the shaft 55 is provided with a plurality of spherical teeth 59 engaged with cooperating spherical teeth of an internal gear 60 which, in the form shown, is set in a recess portion 51 at the rear end of the shaft 4 and held therein as by studs 62 passing through flanges 63. The arrangement is such that the cooperating spherical gear teeth just mentioned constitute a flexible coupling to provide a continuous drive connection between stub shaft 55 and the main drive shaft 4 during all permissible vibratory or oscillatory movements of the main shaft 4 while the machine is in operation.

The drive gearing above described is so arranged to rotate the weight 3 in a direction opposite to that of the shell 1 with its cutter bits 2b. This gearing is shown diagrammatically in Figure 6, wherein the gears are disposed as seen from the front of the machine. Assuming that the motor pinion 53 rotates at 1150 R. P. M., the gears are arranged so as to drive the main shaft 4 at approximately 190 R. P. M. and to drive the shell 1 in the opposite direction at approximately 90 R. P. M. This affords a
A vibratory or oscillating movement of the shell 1, weight 3 and the parts suspended for rotation therewith is set up by the rotation of the weight and shaft, as described. Any desired vibratory force may be obtained within permissible limits by providing a suitable weight for the shell and its co-rotating parts on the one hand, and a suitable weight for the off-center weight 3 and its co-rotating parts, on the other. When the parts are put into rotation, the shell will be caused to vibrate transversely or radially of the main axis AC of the drive shaft 4 approximately 23 times for each full rotation of said shell.

Considering now the path of movement produced at the point of each digging bit 2a on the shell 1 due to the combined rotation and vibratory movement of said shell, Figure 7 shows a motion pattern described by a single bit point in its plane of rotation as produced with a digging head driven by the gear shown and described in connection with Figure 6.

As will be noted from the motion pattern of Figure 7, each bit point follows a generally circumferential path, but not in the usual series of successive loops 70 during each full rotation, which loops project outwardly or radially of the general axis of rotation of drive shaft 4. From the shape of these loops, it will be understood that each bit point makes about 23 successive relatively rapid outward picking movements toward the coal during each revolution of the shell. Moreover, the bit point momentarily reverses its forward movement just after it reaches each extreme limit of outward picking movement. This type of picking action is found to be especially effective in dislodging certain types of coal, as for instance friable coal, as it tends to dislodge such in larger lumps than is the case with other types of bit motions. It will be further understood that the motion pattern of the bit points shown in Figure 7 is that described without any digging load on the shell and that this pattern is subject to considerable modification when the shell is in operation under varying digging loads against a coal face. In general, however, the several bits will constantly tend to approach the motion pattern shown as resistance of the coal decreases.

Another illustrative form of drive gearing is shown diagrammatically in Figure 8 which produces a motion pattern substantially as shown in Figure 9. In this form of gearing, the shell and weight are also rotated in opposite directions as before, but certain gears are of different sizes to produce a substantially lower ratio between the speeds of rotation of the weight and shell. Thus, in this modified form, pinion 48 is larger than the corresponding pinion 45 of Figure 6 and the gear 44a is smaller than the corresponding gear 44 of the latter figure. This change in gearing produces a ratio of substantially 8 to 1. The motion pattern of each cutting bit resulting from this reduced speed ratio is shown in Figure 9. As will be seen from this latter figure, the bit is set in a direction approximately at right angles to the general axis of main shaft 4 without any looped or retrograde movement. This type of bit action may be found to act more effectively in dislodging certain types of coal, such as so-called “woody” coals.

Figure 10 shows diagrammatically still another modified form of drive gearing for the vibratory assembly wherein both the weight 3 and the shell 1 are rotated in the same direction. In this form of gearing, the motor pinion 53 and the drive shafts 49 and 39 may be disposed in the same relationship to each other as before, but different sized gears are used on said shafts, in different meshed relationship. Thus, in Figure 10, the motor pinion 72 is meshed with a gear 73 which drives gear 54 on shaft 55 connected to the main drive shaft to drive the latter shaft in a clockwise direction. The gear 73 also has gear 76 rotating therewith which is meshed with the gear 77. The latter gear rotates the tubular shaft 39 which drives the shell 1 in a clockwise direction, at a ratio of approximately 23 to 1. This results in the motion pattern for each bit point substantially as shown in Figure 11.

It will be observed from this motion pattern that each bit point follows a generally circumferential path including a series of successive loops 71, but that said loops extend inwardly toward the approximate center of rotation of the shell instead of outwardly, as is the case with the looped pattern shown in Figure 7. This means that the bit acts with a picking action but remains in an outwardly projected shearing position relative to the coal for a longer period of time than is the case with the motion pattern shown in Figure 7. This modified motion pattern is particularly effective for certain types of coal which are more readily dislodged by a combined picking and shearing action.

The use and operation of my vibratory digging mechanism may now be described as follows:

The digging head mechanism mounted on platform 10 may be adjustable supported on any suitable base structure to position or move the digging head 1 into operative relation to the coal face, with the digging bits 2a in engagement with the coal. Many conventional base structures may be provided for this purpose. In the illustrative form of machine shown in Figure 1, the mobile base 11 is somewhat similar to that disclosed in the application of Charles E. Berry, Serial Number 142,469, hereinafter referred to, and includes a base frame 38 with a turntable 33 mounted thereon. The platform 10 carrying the vibratory assembly is mounted, for vertical pivoted movement relative to the turntable by two upright hydraulic cylinders 34 disposed at widely spaced points near the front end of the turntable, to swing said platform about a trunnion support 34a disposed toward the rear of said turntable. The base frame 32 may, as usual, be provided with a pair of endless tread supports 35 along opposite sides thereof, driven from motors 36, 37 on the rear end of the base frame. It will be understood, however, that the present invention is not limited to any specific form of supporting and actuating means for moving or positioning the digging head with respect to the coal face, since such moving or positioning means may be varied widely in utilizing my improved form of vibratory digging head under different conditions of mining.

Accordingly, many of the means provided for positioning or moving the digging head into contact with the coal, the shell 1 with its digging head is moved by power into contact with the solid coal face so that the cutter bits 2a engage the coal and dislodge it in broken down form for subsequent removal from the mine in any suitable manner.

While it is evident that the shell 1 may be
employed as a drilling or boring tool by feeding it forwardly in the direction of the general axis of rotation of the rotating parts, it will be understood that the digging head operates most effectively by swinging it in planes laterally or transversely to its general longitudinal axis of rotation, in which planes the vibratory movements of the shell are also directed. Referring now more particularly to the novel features of my improved form of digging head, it will be understood that the rotating shell 1, weight 3, and those rotating portions of the drive gearing which are relatively free to vibrate or oscillate with the shell and weight, constitute what may be termed the vibratory assembly of the machine, while the base 11, platform 10, motor 9, brackets 21 and 22 and those portions of the drive gearing carried by said brackets provide a non-vibratory support for the vibratory assembly.

In practice, the shell and weight should be rotated at speeds in excess of the critical speed or natural period of vibration of the vibratory assembly because rotation at speeds below such natural period of vibration causes most of the vibrations set up in the system to be transmitted to the supporting structure. But, when the speed is increased above the natural period of vibration, the resulting vibrations are confined almost entirely to the vibratory assembly, and the effects of such vibrations on the platform 15 and base 11 are reduced to a minimum.

The arrangement, whereby the main drive shaft 4 constitutes the sole supporting means for both the weight 3 and the shell 1, aids materially in utilizing the vibrational effects on the vibratory assembly for dislodging the coal to the maximum, while reducing the effects of such vibrations upon the non-vibratory supporting mechanism to a minimum. As previously explained, the main drive shaft 4 is rotatably supported so as to oscillate universally about the point A at its extreme rear end. The amplitude of oscillation of this shaft, as well as the remainder of the vibratory assembly, is controlled by the yielding discs 29 and 30, disposed at a substantial distance forwardly from point A. The yielding discs 29 and 30 constitute the only substantial supporting and damping means for the vibratory assembling. The drive shaft 4 must therefore be of very substantial size and strength, as compared for instance with the tubular drive shaft 39 through which the shell 1 is rotated, but which is flexible connected to the shell so as to provide no transverse support or damping effect on the latter. The shell is rotatably mounted on the outer end section 6a of the main drive shaft 4 so as to be entirely supported by the latter against endwise thrusts, transverse oscillations and transverse digging reactions of the vibratory assembly as the shell is in operative engagement with the coal.

Referring now in greater detail to the novel arrangement wherein the general axis AC of the main drive shaft 4, when extended, passes substantially through the center of gravity of the shell 1 and the off-center weight 3 while the shell and weight rotate on the slightly offset longitudinal axis DE, as previously described, the advantages of this arrangement may now be explained as follows:

Assuming that the mass of shell 1 is distributed substantially uniformly about its own axis of rotation DE, as will usually be the case, the center of gravity of shell 1 will be located on axis DE. The center of gravity of weight 3, however, is located at some point on the opposite side of the extended main axis AC so that said main axis and the centers of gravity of the shell and weight, respectively, are all in the same plane. The relative distance between the respective centers of gravity of the shell and weight from said extended main axis will vary inversely with the total weights of the shell and weight, in accordance with a well-known law relating to relatively rotating bodies. It will be observed that, due to the preferred arrangement whereby the combined centers of gravity of the shell and weight are located on the extended main axis AC of drive shaft 4, which main axis is also centered in the bearings 19 and 33 for said main shaft, the entire vibrating assembly carried by and with the main drive shaft will tend to rotate in balanced relation about the main axis AC when the parts are being rotated at normal operating speeds, without any transverse load on the shell due to lateral contact with the coal face. Nevertheless, due to the axial or offset mounting of the shell 1 in opposed relation to the center of gravity of the off-center weight 3, the shell 1 will be simultaneously rotated and vibrated to produce a motion pattern for the digging bits such as illustrated in Figures 7, 8, or 11, depending upon the speed ratio and relative direction of movement of the shell and weight. The effects of such vibratory motion, however, will be almost entirely confined to the shell and weight, particularly when the parts are being rotated above the critical speed of the assembly, as previously described. When the digging head is moved laterally into digging engagement with the coal face, a resulting lateral thrust will tend to oscillate the drive shaft about point A at the extreme inner end of said shaft while any resulting deviation or oscillation effective on the shaft will be taken up by the yielding bearing support, including the rubber discs 29 and 30, which rotatably supports the drive shaft substantially at point B. As the digging head or shell works itself gradually into the coal face, the vibrating movements of the bits operating successively upon the coal face will dislodge the coal with a continuous combined picking and rotating movement, with the rubber discs 29 and 30 operating under shearing stresses, depending upon the amount of lateral pressure necessary for feeding the bits into the coal face.

I claim:

1. In a digging machine, a frame, a main drive shaft rotatably supported on said frame for universal oscillatory movements relative to its normal axis of rotation, said main shaft having a portion at the oscillatory end thereof offset axially from the normal axis of said main shaft, a hollow shell having peripheral digging bits and rotatably mounted on said axially offset portion of said main shaft, a weight fixed on said axially offset shaft portion, the center of gravity of said weight being axially offset from the main axis of said shaft in a direction opposite to that of said axially offset portion of said shaft, and means for rotating said shell independently of said weight.

2. A machine in accordance with claim 1, wherein the normal axis of rotation of the main shaft is substantially in longitudinal alignment with the combined center of gravity of said shell and said weight.

3. A machine in accordance with claim 1, wherein the means for rotating the shell includes
a hollow drive shaft through which the main shaft extends, which hollow drive shaft has a universal-jointed connection with said shell in non-supporting relation thereto.

In a digging machine, a frame, a main drive shaft, means on said frame for driving one end of said shaft including a universal connection affording limited oscillation of the latter relative to its normal axis, bearing means intermediate the ends of said shaft affording limited yielding universal oscillation of said shaft, a hollow shell wholly supported in rotatable relation on the outer end of said shaft and having peripheral digging means thereon, an off-center weight fixed on the end of said shaft within said shell, and means on said frame for rotating said shell independently of said drive shaft including a hollow drive shaft through which said main drive shaft extends, said hollow shaft having a universal-jointed drive connection with said shell in non-supporting relation thereto.

A machine in accordance with claim 4 wherein the bearing means for the main shaft comprises an annular bearing member, an annular support on said frame surrounding said bearing member, and a disc of yieldable material in supporting relation between said bearing member and said annular support.

A machine in accordance with claim 5 wherein the disc is connected laterally between axially aligned portions of said bearing member and annular support, and is yieldable in shear in its own plane during oscillations of said main shaft.

In a digging machine, a frame, a main drive shaft, means on said frame for driving one end of said shaft including a universal connection affording limited oscillation of the latter about a fixed point coincident with its normal axis, bearing means intermediate the ends of said shaft affording limited yielding oscillation of said shaft universally about said fixed point, a hollow shell wholly supported in rotatable relation on the outer end of said shaft and having peripheral digging means thereon, an off-center weight fixed on the end of said shaft within said shell, and means on said frame for rotating said shell independently of said drive shaft, the bearing means for the main shaft including an annular bearing member having a pair of opposed axially-facing cheeks, an annular bearing support on said frame surrounding said bearing member and having a pair of cheeks opposite the axially-facing cheeks of said annular bearing member, and a pair of discs of yieldable material interposed between the two pairs of opposed cheeks and fixed thereto, so as to permit limited yielding of said bearing member both axially and transversely relative to said bearing support.

A machine in accordance with claim 4 wherein the means on said frame for rotating the shell also includes a gear rotatably supported on the bearing means and having the main shaft extending freely therethrough and connected through a universal joint with the rear end of the hollow drive shaft for the shell.

A machine in accordance with claim 10 wherein a drive motor is mounted on the frame and said drive motor is connected through independent gear trains for driving the inner end of the main drive shaft and the hollow shaft at different speeds.

A machine in accordance with claim 11 wherein the drive motor and intermediate drive gearing normally rotate the oscillatory assembly comprising the shell, the weight and their respective drive shafts, at a speed differing from the critical speed of said assembly.

ROBERT A. MCCAULUM.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>957,957</td>
<td>Hirst</td>
<td>May 17, 1910</td>
</tr>
<tr>
<td>2,239,912</td>
<td>Bally</td>
<td>Jan. 28, 1941</td>
</tr>
<tr>
<td>2,572,403</td>
<td>Stevenson</td>
<td>Oct. 23, 1951</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>66,420</td>
<td>Norway</td>
<td>July 5, 1943</td>
</tr>
</tbody>
</table>