A UDD mining machine provided with a control system directs the movement of the bucket within a prescribed carry envelope to limit unequal wearing of the hoist lines. In one construction, the control system directs the bucket within a range of motion where the loads on the hoist lines are kept within a prescribed variance of each other during the carry phase or most of the carry phase of a digging cycle. Movement of the bucket will be controlled by the mining machine with the inventive control system so that, in the carry phase, the loads applied to the front hoist line are within, for example, 5%, 10% or 15% of the loads applied to the rear hoist lines. This general equalizing of the loads in the hoist lines results in longer wear life for the front hoist lines, and generally equal wearing of the front and rear hoist lines to enable simultaneous replacement.
UDD DRAGLINE BUCKET MACHINE AND
CONTROL SYSTEM

FIELD OF THE INVENTION

[0001] The present invention pertains to a machine with a unique control system for a universal dig and dump mining operation.

BACKGROUND OF THE PRESENT INVENTION

[0002] Universal dig and dump (UDD) mining operations involve the use of dragline buckets that are controlled by UDD mining machines having front hoist lines, rear hoist lines and drag lines, such as disclosed in U.S. Pat. Nos. 6,705,031 and 6,826,466. While these operations have provided benefits, they have been particularly hard on the front hoist lines; i.e., the front hoist lines tend to be damaged or to wear much faster than the rear hoist lines. Such wearing requires frequent replacement of the front hoist lines, which results in the use of more hoist line and in frequent downtime of the equipment. Moreover, the front hoist lines frequently wear at unequal intervals from the rear hoist lines resulting in even increased equipment downtime as the hoist lines are replaced separately. The front hoist motors also have more power, which can further lead to front hoist rope problems.

SUMMARY OF THE INVENTION

[0003] The present invention pertains to a UDD mining machine that moves the bucket during the carry phase of a digging operation within a range of motion that is predetermined at least in part by the expected relative loads on the hoist lines.

[0004] In one aspect of the present invention, the bucket is moved through a carry envelope for an improved UDD mining operation that reduces the loading on the front hoist line and enhances the efficiency of the mine.

[0005] In one aspect of the invention, a control system for a UDD mining machine directs the movement of a loaded bucket within a prescribed carry envelope to limit unequal loading of the hoist lines. The control system directs the operator to move the UDD bucket within the prescribed carry envelope or, alternatively, move it directly under computer control. In one preferred construction, the control system directs the bucket to be moved within a range of motion where the loads on the hoist lines are kept within a prescribed variance of each other during the carry phase or most of the carry phase of a digging cycle. For example, movement of the bucket will be directed by the inventive control system so that the loads applied to the front hoist line are within, for example, 5%, 10% or 15% of the loads applied to the rear hoist line. This general equaling of the loads in the hoist lines results in longer wear life for the front hoist line, and generally equal wearing of the front and rear hoist lines to enable simultaneous replacement.

[0006] In another aspect of the invention, the control system for a UDD mining machine directs the movement of the bucket within a carry envelope defined by borders that widen, and which preferably widen generally at an increasing rate, in a direction opposite to the pulling of the drag line.

[0007] In another aspect of the invention, the control system for a UDD mining machine directs the movement of the bucket in the carry phase of a digging cycle to predominantly move under a prescribed datum having a generally bell-shaped curve.

[0008] In another aspect of the invention, the control system for a UDD mining machine directs movement of the bucket in the carry phase of a digging cycle to move under a prescribed datum having a slope that generally increases in a direction opposite the pulling of the bucket during the digging phase.

[0009] In another aspect of the invention, the control system directs the bucket during the carry phase to be moved predominantly below an upper datum where the variation between the loads on the hoist lines is at predetermined level.

[0010] In another aspect of the invention, the control system directs the bucket to be predominantly moved during the carry phase in a range of motion which on average loads the front hoist line at a predetermined higher level than the loads on the rear hoist lines to control the replacement time for the front hoist line.

[0011] In another aspect of the invention, the control system directs the bucket to be moved during the carry phase in a range of motion that depends on the expected relative loads on the hoist lines.

[0012] In another aspect of the invention, the control system directs the movement of the bucket in a carry envelope where the overall magnitude of the loads on the hoist lines is reduced rather than equalizing the hoist line loads.

[0013] In another aspect of the invention, a UDD machine commonly has more motors supporting the front hoist lines than the rear hoist lines. The control system can direct the bucket through a carry envelope that maximizes the carrying power of the additional motors. For example, the prescribed carry envelope may equalize the loads carried by each motor rather than in each hoist line.

[0014] In another aspect of the invention, the bucket for a UDD mining operation is provided with a plurality of pairs of connection points for either or both of the front and rear hoist lines. In this way, the carry envelope for a particular bucket can be adjusted for a particular mining operation to maximize the equaling of the hoist line wear. Multiple connection points can also provide flexibility in accommodating and maximizing performance.

[0015] In another aspect of the invention, the bucket for a UDD mining operation is formed with a bottom wall, a rear wall and a pair of sidewalls that are connected to define a front digging edge and a bucket cavity. The bucket is provided with connection points to facilitate the connection of front and rear hoist lines to the bucket. At least one of the connection points for coupling the rear hoist line to the bucket is located forward of the rear wall to provide improved wearing of the bucket during use for certain mining operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a schematic illustration of a UDD mining operation.

[0017] FIG. 2 is a side view of a UDD bucket.

[0018] FIG. 3 is an enlarged side view of a trunnion for the UDD bucket.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The present invention pertains to a UDD mining machine wherein the bucket is controlled by independently operated front and rear hoist lines as well as a drag line, such as disclosed in U.S. Pat. Nos. 6,705,031 and 6,826,466, both of which are incorporated herein by reference. Briefly, a UDD operation is a dragline mining operation wherein a bucket is controlled solely by the attachment of hoist lines, such as ropes, cables or chains. With reference to FIG. 1, a UDD operation 10 includes a machine 12 situated at a base location that is typically at or near ground level. The machine includes an elongate boom 14 that extends over the mining site, which typically is a large pit. One or more rear hoist lines 16 extend downward generally from a free end 18 of the boom to engage a rear portion of bucket 20. Similarly, one or more front hoist lines 22 extend downward from boom 14 to connect to a front portion of bucket 20. Hoist lines 16, 22 operate independently to carry and dump the bucket through the digging cycle. One or more drag line 24 connects to a front portion of bucket 20 to pull the bucket along the ground in order to fill the bucket. The UDD machine 12 further includes a control system with the appropriate motors, operator controls and computer for controlling the movement of the bucket via the hoist and drag lines. Ordinarily, other than the attitude of the bucket which is automatically controlled by the computer, the operator manually controls the movement of the bucket in a digging operation. For convenience, this application will discuss an operation that includes a single rear hoist line, front hoist line and drag line, though operations with a plurality of each kind of line or a mixed operation of single and multiple lines is possible.

[0021] In one common digging cycle, the bucket is first set on the ground at the beginning of a pulling or digging phase in which the drag line pulls the bucket along the ground to fill it. Once the bucket is loaded, it is hoisted off the ground by the hoist line and moved from the terminus end of the digging phase to the dumping location, which is the carry phase of the digging cycle. The carry phase is followed by a dumping phase where the front hoist line is lowered relative to the rear hoist line to dump the earth material out of the bucket via its open front end. The bucket is then returned, in a return phase, to the beginning of another digging phase. In the present invention, the operation of the hoist and drag lines in a UDD operation is directed by a computer 25 for the control system. Of course, the computer may be the same unit controlling the attitude of the bucket or a different unit.

[0022] While UDD operations provide better control of the bucket than conventional dragline operations, they tend to suffer from undue damage, loading and wearing of the front hoist line. As a result, the front hoist line wears more quickly than the rear hoist line and, in some cases, as much as three to four times as fast. Premature wearing of the front hoist line results in increased usage of hoist line and in excessive downtime for the mining equipment. Moreover, the front and rear hoist lines frequently wear at uneven intervals requiring separate replacement of the front and rear hoist lines and even more equipment downtime.

[0023] It has been determined that such excessive and unequal wearing of the front hoist line is caused primarily by unequal loading of the hoist lines during the carry phase of a digging cycle. Ordinarily, during the carry phase, the load on the rear hoist line tends to be relatively constant. In many potential positions during the carry phase, the pull of the drag line 24 will tend to generate high loads on the front hoist line 22, particularly as the bucket nears boom 14. When the bucket is at lower positions within the mine, the loads on front hoist lines 22 tend to be less as compared to many positions when the bucket is high in the mine. The pull of drag line 24 on front hoist 22 is reduced in some positions and in others actually bears some of the hoisting load to reduce the load on the front hoist line. While it is preferable to maintain generally equal loading of the front and rear hoist lines throughout the carry phase of the digging cycle, it is typically more important to do so in the higher reaches of the mine because of these higher loads.

[0024] It has been determined that loading of the front and rear hoist lines, and particularly the front hoist line, is dependent on several factors including the position of the bucket under boom 14, the center of gravity of the loaded bucket (i.e., the loaded center of gravity), and the location of the front and rear connection points relative to the loaded center of gravity. A change of any of these factors will result in more or less loading of the front hoist line. As noted above, the loads on the rear hoist line, though changing, generally tend to remain relatively constant through most carry positions.

[0025] In one example, bucket 20 includes a bottom wall 26, a rear wall 28, and a pair of sidewalls 30 coupled together to define a front digging edge 32 and an inner bucket cavity. The digging edge includes a series of spaced apart teeth 34 for penetrating the ground and facilitating loading of the bucket when pulled along the ground by the drag line 24. The drag line usually branches forward of the bucket to connect to each side of the bucket. An arch 36 couples the upper front ends of sidewalls 30; although an arch is not required. Front hoist line 22 is coupled to arch 36 via front connection point 38. Rear hoist line 16, which usually branches above the bucket, attaches to each sidewall 30 via rear connection points 40. Nevertheless, connection points 38, 40 could be fixed to other parts of the bucket, and buckets having other designs could be used. As examples only, front connection points could be fixed to sidewalls 30, such as disclosed in U.S. Pat. No. 6,705,031, and/or the rear connection points could be fixed to the rear wall 28. In any event, the front connection point(s) 38 is fixed to a front portion 44 of bucket 20 and rear connection points 40 are fixed to a rear portion 46 of the bucket. Drag line 24 is coupled to the front edges 48 of sidewalls 30 via drag connection points 50.

[0026] During use, the bucket is loaded with earthen material in each digging phase. While the loaded center of gravity may shift slightly from load to load, an average loaded center of gravity 52 can be determined for each particular bucket. The loaded center of gravity 52 is also a factor of the density of the material to be gathered as denser loads will tend to shift the center of gravity rearward. The location of connection points 38, 40 can be determined in a two-dimensional format (i.e., height and length) relative to the loaded center of gravity 52. With these three known location points 38, 40, 52, the loads carried by each hoist line 16, 22 can be determined and mapped for all carry positions.
(i.e., positions where the bucket may be in a carry phase of a digging cycle) within the mine site. It has been determined that relatively equal loading of hoist lines 16, 22 can be achieved when the bucket is maintained within a prescribed carry envelope 54.

In one example, front hoist line 22 is coupled to front connection point 38 and rear hoist line 16 is coupled to rear connection points 40a. In the carry phase of a loaded bucket, hoist lines 16, 22 will carry generally the same load (i.e., within about 5% of each other) if the bucket’s loaded center of gravity 52 is kept within a carry envelope 54a defined by an upper datum or border 56a and a lower datum or border 56b. With reference to FIG. 4, the zero point of the plot is the base position of boom 14, i.e., where boom 14 is coupled to the base 13 of machine 12. The vertical and horizontal axes in the plot represent the vertical and horizontal distances the bucket may be relative to the zero point. As can be seen (FIG. 4), in this case, upper border 56b has a curved, generally bell-shaped configuration. In this example, the slope of the curve generally increases as the border extends away from the zero point and toward free end 18 of boom 14. Further, carry envelope 54a generally widens and, in this example, generally at an increasing rate as it extends away from machine 12 base 13. Borders 56, 58 extend into and out of the paper of the plot in FIG. 4 to control the lift of the bucket irrespective of the lateral swinging of boom 14.

As one illustration, if the terminus of the digging phase locates bucket 20 at point 60, bucket 20 will be directed by computer 25 for the control system to follow a carry path to the dump site 61 that stays beneath upper border 56a to ensure that the loads in each of the front and rear hoist lines remain relatively equal; i.e., the control system would direct the operator to move the UDD bucket within the prescribed carry envelope (e.g., with a light indicator or other indication of when the bucket is outside of the prescribed carry envelope). Alternatively, the bucket could be moved directly under computer control. As can be appreciated, this carry path 62 from point 60 to the dump site 61 (one example illustrated in FIG. 4) will have an axial configuration (lateral motion of bucket 20 is not shown in the plot) that is generally bell shaped so that the bucket generally moves more horizontally in the earlier portion of the carry phase and generally more vertical in the latter stages of the carry phase. The actual path may vary from that which is shown depending on various factors such as the swing speed and swing angle. In the past, it was common for the bucket to generally follow a carry path 64 from point 60 to dump site 61 that was axially linear to reduce the overall length of travel. While the distance to the dump site is lessened, it causes the bucket to move outside of carry envelope 54a, i.e., above upper border 56a, and to thereby apply higher loads to front hoist line 22 as compared to rear hoist line 16. This repeated additional loading causes front hoist line 22 to wear out more quickly than rear hoist line 16.

The position of carry envelope 54 can be adjusted in the mine site by changing the position of one or more of the connection points 38, 40. In one example, front connection point 38 remains unchanged, and rear connection point 40 is moved rearward from location 40a to location 40b. As seen in FIG. 3, connector 66 can be attached via a pin 68 to hole 70 to define a first connection point 40a or to hole 72 to define a second connection point 40b rearward of the first connection point. Of course, other ways of connecting or changing the connection points could be used. By moving rear connection point 40 rearward to location 40b, the carry envelope 54 drops relative to the zero point so that upper and lower borders 56, 58 are lower relative to boom 14 and lower into a mining pit (FIG. 5). As with the first connection points 38, 40a, these second connection points 38, 40b define a carry envelope 54b with an upper border 56b and a lower border 58b. Further, the carry envelope 54b generally widens, and in this example, generally at an increasing rate as it extends axially away from machine 12. The carry path for bucket 20 with this second set of connection points 38, 40b is directed by the control system to stay between borders 56b, 58b so that the loads on hoist lines 16, 22 remain within about 5% of each other. This connection arrangement for this bucket may be preferred in a deeper mine site. Moreover, the connection points could be selectivity chosen for a bucket that is designed for a particular mine in order to maximize the ability of the bucket to travel within the preferred carry envelope for that mine or mine plan. When designing the connection points for a bucket to be used in a particular mine site, greater attention will preferably be paid to the expected movement of the bucket through the higher regions of the mine. In a preferred embodiment for many mines, the rear connection points 40 are located forward of the rear wall 28 of the bucket to provide a more optimal carry envelope. Nevertheless, rear connections could be along rear wall 28.

As can be appreciated, the position of the carry envelope 54 can be adjusted up or down within the mine or its shape changed to narrow or widen depending on whether connection points 38, 40 are moved rearward/forward or up/down relative to the loaded center of gravity 52. Irrespective of these changes, computer 25 for the control system, with the proper input of data, will direct the movement of the bucket for the carry phase to stay within the prescribed carry envelope to the dump site. The carry envelope will generally be defined by upper and lower borders 56, 58 that diverge generally at an increasing rate as the carry envelope extends away from machine 12. Upper border 56 in many cases will generally have a configuration that resembles a bell shape (i.e., that flares upward at the outer range of the bucket’s motion). The control system will often direct the bucket to move primarily in a horizontal direction in early portions of the carry phase and primarily in a vertical direction in later phases of the carry phase. Additional connection points can also be added to bucket 20 to provide further variations in the carry envelope. These additional connection points may be front and/or rear connection points.

At times, however, a mine will have a certain layout that precludes the bucket from moving solely within a carry envelope wherein the loads on the hoist lines 16, 22 are kept generally equal (i.e., within about 5% of each other). This may occur, for example, when the mine pit is deeper than the operating carry envelope 54 so that the bucket ends its digging phase below lower border 58. It may also occur, for example, when the dump site is higher than carry envelope 54 so that the bucket must travel above the upper border 56 to dump its load. In these cases, the control system directs the bucket to move predominantly within the desired carry envelope 54 so that the application of higher loads on the front hoist line is minimized. Under such circumstances, if the bucket included multiple connection points, the hoist lines would preferably be set to enable
movement of the bucket beneath the upper datum 56 even if it meant substantial movement below the lower datum because of the difference in the magnitudes of the loads on the front hoist line at these different positions in the mines.

Moreover, due to higher loads on the front hoist line in certain higher regions of a mine as compared to the lower regions, the control system can be set to direct the movement of the bucket along a carry path that is kept predominantly beneath an upper datum 56 without regard to a lower datum 58. Under these parameters, the upper datum is defined in the same way, i.e. the boundary where the load on the front hoist line is within a predetermined load differential (e.g., within 5%, 10%, etc.) as compared to the load expected on the rear hoist line.

Operation outside of a carry envelope that ensures generally equal loading of hoist lines 16, 22 may also occur, for example, when a bucket has only a single set of connection points that may not be able to maximize efficiency for a particular mine. In these cases, it may be necessary to operate the bucket for substantial periods outside of this desired carry envelope. In such cases, the control system can be set to direct the movement of the bucket within or at least predominantly within a carry envelope where the front and rear hoist lines are kept within a prescribed load percentage of each other which may be greater than a 5% difference.

For instance, with reference to FIG. 6, carry envelope 54c. for a particular bucket, with borders 56e, 58c defines a range of motion for the bucket where the loads on hoist lines 16, 22 remain within about 5% of each other. The particularities of the mine may dictate that for a particular bucket substantial portions of the carry phase may need to occur outside of a carry envelope 54c. In such cases, the control system can be set to direct the movement of the bucket within or predominantly within a carry envelope 54d) with borders 56d, 58d where the loads on hoist lines 16, 22 are kept with a range of about 10% of each other. Alternatively, the control system could be set to direct the movement of the bucket within a carry envelope 54e with borders 56e, 58e where the loads on hoist lines 16, 22 are kept within 15% of each other. As can be appreciated, the control system can be set to dictate that the hoist lines stay within a certain prescribed load percentage of each other or as closely as possible to the desired variance to keep hoist line loads as close as possible. Such control can be overridden as much as possible under the given circumstances unequal loading of the hoist lines and the premature wearing of the front hoist line.

There are times also when it may be desirable to operate the UDD machine to balance the speed of the digging operation against the frequency of replacing the front hoist line. For instance, the digging cycle may be lengthened by having the control system direct the bucket to move in a range of motion where the loads in the front and rear hoist lines are predominantly within 5% of each other during the carry phase. As an alternative, the operator may set the control system to direct the movement of the bucket along a path where the loads in the front hoist line are within a predetermined difference of the loads in the rear hoist line by more than 5% in order to shorten the digging cycle and increase the production of the machine even if not required by the mine layout.

In one example, the bucket is directed to move predominantly (at least in the upper regions of the mine) along a carry path where the load on the front hoist line is about 15% higher than the load on the rear hoist line. Further, the control system can be set so that the load on the front hoist line is kept within a certain variation of the carry path that approximates a 15% difference in the front and rear hoist line loads. For instance, the bucket can be moved within a range of motion wherein the hoist line loads vary upward or downward 5% (or other value) from the prescribed path—that is, the bucket predominantly moves within a range of motion where the load on the front hoist line is 10-20% higher than the loads on the rear hoist line. In this way, the operator can balance the downtime caused by replacing the front hoist line with the speed of the digging cycle in an effort to maximize the overall production of the mine.

In another example, the control system can be set to permit even higher variations in hoist line loads (i.e., more than 15%) provided sufficient shortening of the digging cycle is gained. In other words, the overall production of the UDD machine mining can be maximized in some operations by accepting more frequent replacements of the front hoist lines and achieving a shorter digging cycle. The control system can achieve optimum bucket movement during the carry phase by factoring the duration of the digging cycle, the output production of each digging cycle, the variations in loads between the hoist lines, and the downtime caused by replacement of the front hoist line.

Also, in certain mines, the front hoist line suffers abrasion wear near connection point 38 so that the terminal end of the front hoist becomes unacceptably worn even though the remainder of the hoist line has not worn as a result of the hoist loads. In such cases, the worn end of the front hoist line can be cut off and the front hoist line reattached in order to lengthen the use of the front hoist line, i.e., until the overall length of the front hoist line becomes too short to be used. Under these circumstances, the control system may be set to direct bucket movement along a path where the wearing of the hoist line due to uneven loading of the front hoist line corresponds with the time in which the front hoist line needs to be replaced due to shortening caused by abrasion wear. In this way, the operator may be able to shorten the time for the digging cycle and control front hoist line wear caused by hoist loads to correspond to the time when the front hoist line would need to be replaced for other reasons such as shortening caused by abrasion wear.

As discussed above, the operation of the drag line affects the loads on the hoist lines. In another alternative, the bucket may be moved along a carry envelope to minimize the overall loads on the hoist ropes rather than equalizing the loads in the front and rear hoist lines.

Also, as discussed above, it is common for UDD machines to have more motors supporting the front hoist lines than the rear hoist lines. As an alternative, the bucket can be directed to move through a carry envelope that generally equalizes the loads carried by each motor rather than in each line.

Also, in a mixed line operation, e.g., where two front hoist lines are used but only one rear hoist line, the bucket can be moved through a carry envelope where the loads in each line are generally equal (i.e., where the overall load on the front hoist lines is twice the load in the single rear hoist line).

Various other embodiments as well as many changes may be made without departing from the spirit and broader aspects of the invention as defined in the claims.
1. A UDD mining machine comprising:
a bucket including a cavity for receiving earthen material,
a front portion having a front digging edge, and an
opposite rear portion;
a boom;
hoist lines for connecting the bucket to the boom to move
the bucket vertically relative to the boom, one said hoist
line being a front hoist line connecting the front portion
of the bucket to the boom to independently raise and
lower the front portion of the bucket, and another said
hoist line being a rear hoist line connecting the rear
portion of the bucket to the boom to independently
raise and lower the rear portion of the bucket;
a drag line for pulling the bucket in a digging operation;
and
a control system for directing the movement of the bucket
in a digging operation which includes a digging phase
where earthen material is gathered into the cavity of
the bucket, a dump phase where the gathered earthen
material is discharged from the bucket, and a carry
phase where the bucket is moved from a first location
at an end of the digging phase to a second location
where the earthen material is discharged from the
bucket, the control system directing the bucket to move
predominantly within a range of motion in the carry
phase so that a load on the front hoist line is generally
maintained within a predetermined variance relative to
a load on the rear hoist line.

2. A UDD mining machine in accordance with claim 1
wherein the control system directs the bucket to move in the
carry phase so that the load on the front hoist line is
maintained to be within about five percent of the load on the
rear hoist line.

3. A UDD mining machine in accordance with claim 1
wherein the control system directs the bucket to move in the
carry phase so that the load on the front hoist line is
maintained to be within about ten percent of the load on the
rear hoist line.

4. A UDD mining machine in accordance with claim 1
wherein the control system directs the bucket to move in the
carry phase so that the load on the front hoist line is
maintained to be within about fifteen percent of the load on the
rear hoist line.

5. A UDD mining machine in accordance with claim 1
wherein the control system directs the bucket to move in the
carry phase predominantly below an upper datum that
generally has an increasing slope in a direction opposite the
pulling of the bucket by the drag line.

6. A UDD mining machine in accordance with claim 1
wherein the control system directs the bucket to move in the
carry phase predominantly below an upper datum that
generally has a bell-shaped configuration.

7. A UDD mining machine in accordance with claim 1
wherein the range of motion widens generally at an increasing
rate in a direction opposite the pulling by the drag line.

8. A UDD mining machine in accordance with claim 1
wherein the control system includes motors, operator con-
trols and a computer.

9. A UDD mining machine in accordance with claim 8
wherein the control system includes an indicator to guide the
operator to move the bucket within the range of motion in the
carry phase.

10. A UDD mining machine in accordance with claim 8
wherein the bucket is moved under computer control within
the range of motion in the carry phase.

11. A UDD mining machine comprising:
a bucket including a cavity for receiving earthen material
therein, a front portion having a front digging edge, and an
opposite rear portion;
a boom;
hoist lines for connecting the bucket to the boom to move
the bucket vertically relative to the boom, one said hoist
line being a front hoist line connecting the front portion
of the bucket to the boom to independently raise and
lower the front portion of the bucket, and another said
hoist line being a rear hoist line connecting the rear
portion of the bucket to the boom to independently
raise and lower the rear portion of the bucket;
a drag line for pulling the bucket in a digging operation;
and
a control system for directing the movement of the bucket
in a digging operation which includes a digging phase
where earthen material is gathered into the cavity of the
bucket, a dump phase where the gathered earthen
material is discharged from the bucket, and a carry
phase where the bucket is moved from a first location
at an end of the digging phase to a second location
where the earthen material is discharged from the
bucket, the control system directing the bucket to move
in the carry phase predominantly below an upper datum
that generally has an increasing slope in a direction opposite to the pulling by the drag line.

12. A UDD mining machine in accordance with claim 11
wherein the control system includes motors, operator con-
trols and a computer.

13. A UDD mining machine in accordance with claim 12
wherein the control system includes an indicator to guide the
operator to move the bucket within the range of motion in the
carry phase.

14. A UDD mining machine in accordance with claim 12
wherein the bucket is moved under computer control within
the range of motion in the carry phase.

15. A UDD mining machine comprising:
a bucket including a cavity for receiving earthen material
therein, a front portion having a front digging edge, and an
opposite rear portion;
a boom;
hoist lines for connecting the bucket to the boom to move
the bucket vertically relative to the boom, one said hoist
line being a front hoist line connecting the front portion
of the bucket to the boom to independently raise and
lower the front portion of the bucket, and another said
hoist line being a rear hoist line connecting the rear
portion of the bucket to the boom to independently
raise and lower the rear portion of the bucket;
a drag line for pulling the bucket in a digging operation;
and
a control system for directing the movement of the bucket
in a digging operation which includes a digging phase
where earthen material is gathered into the cavity of the
bucket, a dump phase where the gathered earthen
material is discharged from the bucket, and a carry
phase where the bucket is moved from a first location
at an end of the digging phase to a second location
where the earthen material is discharged from the
bucket, the control system directing the bucket to move
in the carry phase in a range of motion that depends on the expected relative loads on the hoist lines.

16. A UDD mining machine in accordance with claim 15 wherein the control system includes motors, operator controls and a computer.

17. A UDD mining machine in accordance with claim 16 wherein the control system includes an indicator to guide the operator to move the bucket within the range of motion in the carry phase.

18. A UDD mining machine in accordance with claim 16 wherein the bucket is moved under computer control within the range of motion in the carry phase.

19. A UDD mining machine in accordance with claim 17 wherein the control system directs the bucket to move in the carry phase so that in the range of motion the loads on the front hoist line are on average at about a predetermined amount higher than the loads on the rear hoist lines to control the replacement time for the front hoist line.

20. A control system for a UDD mining machine having a bucket, a boom, hoist lines for connecting the bucket to the boom and a drag line for pulling the bucket in a digging operation, the control system comprising means for independently adjusting a front one of the hoist lines to vertically move a front portion of the bucket, means for independently adjusting a rear one of the hoist lines to vertically move a rear portion of the bucket, and means for adjusting the drag line to pull the bucket along the ground, the control system directing the movement of the bucket in a digging operation which includes a digging phase where earthen material is gathered into the bucket, a dump phase where the gathered earthen material is discharged from the bucket, and a carry phase where the bucket is moved from a first location at an end of the digging phase to a second location where the earthen material is discharged from the bucket, and the control system directing the bucket to move in the carry phase predominantly within a range of motion so that a load on the front hoist line is generally maintained within a predetermined variance relative to a load in the rear hoist line.

21. A control system for a UDD mining machine in accordance with claim 20 which moves the bucket in the carry phase predominantly below an upper datum that generally has an increasing slope in a direction opposite the pulling by the drag line.

22. A control system for a UDD mining machine in accordance with claim 20 wherein the range of motion in which the control system directs the bucket to move in the carry phase generally widens in a direction opposite the pulling by the drag line.

23. A control system for a UDD mining machine in accordance with claim 20 wherein the range of motion widens generally at an increasing rate in a direction opposite the pulling by the drag line.

24. A control system in accordance with claim 20 further including motors, operator controls and a computer.

25. A control system in accordance with claim 24 further including an indicator to guide the operator to move the bucket within the range of motion in the carry phase.

26. A control system in accordance with claim 24 which moves the bucket under computer control within the range of motion in the carry phase.

27. A control system for a UDD mining machine having a bucket, a boom, hoist lines for connecting the bucket to the boom, and a drag line for pulling the bucket in a digging operation, the control system comprising means for independently adjusting a front one of the hoist lines to vertically move a front portion of the bucket, means for independently adjusting a rear one of the hoist lines to vertically move a rear portion of the bucket, and means for adjusting the drag line to pull the bucket along the ground, the control system directing the movement of the bucket in a digging operation which includes a digging phase where earthen material is gathered into the bucket, a dump phase where the gathered earthen material is discharged from the bucket, and a carry phase where the bucket is moved from a first location at an end of the digging phase to a second location where the earthen material is discharged from the bucket, and the control system directing the bucket to move in the carry phase predominantly below an upper datum that generally has an increasing slope in a direction opposite the pulling by the drag line.

28. A control system for a UDD mining machine having a bucket a boom, hoist lines for connecting the bucket to the boom, and a drag line for pulling the bucket in a digging operation, the control system comprising means for independently adjusting a front one of the hoist lines to vertically move a front portion of the bucket, means for independently adjusting a rear one of the hoist lines to vertically move a rear portion of the bucket, and means for adjusting the drag line to pull the bucket along the ground, the control system directing the movement of the bucket in a digging operation which includes a digging phase where earthen material is gathered into the bucket, a dump phase where the gathered earthen material is discharged from the bucket, and a carry phase where the bucket is moved from a first location at an end of the digging phase to a second location where the earthen material is discharged from the bucket, and the control system directing the bucket to move in the carry phase predominantly within a range of motion that depends on the expected relative loads on the hoist lines.

29. A control system for a UDD mining machine in accordance with claim 28 wherein the control system directs the bucket to move in the range of motion so that the loads on the front hoist line are on average at about a predetermined amount higher than the loads on the rear hoist lines to control the replacement time for the front hoist line.

30. A method of operating a UDD mining machine having a bucket for receiving earthen material and a boom, the method comprising:

- pulling a drag line connected to the material to the bucket along the ground to gather earthen material;
- moving the boom and independently adjusting each of a front hoist line connected to a front portion of the bucket and a rear hoist line connected to a rear portion of the bucket to move the bucket from a first location at an end of the pulling of the bucket by the drag line to a second location where the gathered earthen material is discharged from the bucket so that the bucket moves within a range of motion such that a load on the front hoist line is generally maintained within a predetermined variance relative to a load on the rear hoist line.

31. A method of operating a in accordance with claim 30 where the bucket is moved from the first location to the second location predominantly below an upper datum that generally has an increasing slope in a direction opposite the pulling by the drag line.
32. A method of operating a UDD mining machine in accordance with claim 30 wherein the range of motion generally widens in a direction opposite the pulling by the drag line.

33. A method of operating a UDD mining machine in accordance with claim 30 wherein the range of motion widens generally at an increasing rate in a direction opposite the pulling by the drag line.

34. A method of operating a UDD mining machine having a bucket for receiving earthen material and a boom, the method comprising:
   pulling a drag line connected to the bucket to move the bucket along the ground to gather earthen material;
   moving the boom and independently adjusting each of a front hoist line connected to a front portion of the bucket and a rear hoist line connected to a rear portion of the bucket to move the bucket from a first location at an end of the pulling by the drag line to a second location where the earthen material is discharged from the bucket so that the bucket moves below an upper datum that generally has an increasing slope in a direction opposite the pulling of the drag line.

35. A method of operating a UDD mining machine in accordance with claim 34 wherein the range of motion widens generally at an increasing rate in a direction opposite the pulling by the drag line.

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