United States Patent

Hattrup

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[45] Apr. 4, 1972

[54] ROLLER BUTTER ROCK BORING APPARATUS AND METHOD

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[52] **U.S. Cl.**.....**299/1,** 175/62, 175/96, 299/31, 299/60, 299/86

[51] **Int. Cl.**.....**E01q 3/04**

[58] **Field of Search**.....299/1, 31, 33, 56, 60, 86; 175/62, 95, 96, 319

[56] **References Cited**

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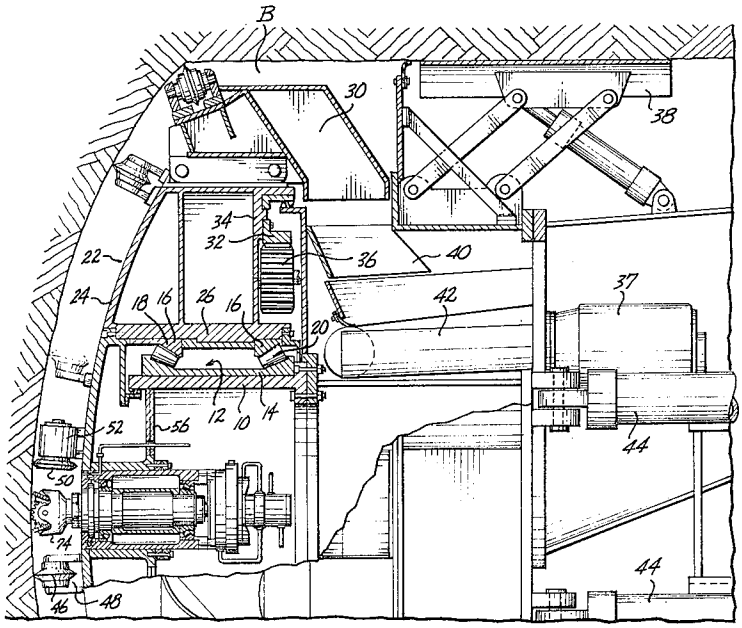
Primary Examiner—Ernest R. Purser

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[57] **ABSTRACT**

Kerf forming disc cutters are closely grouped on a cutter carrier. Where space permits a plural and equal number of cutter wheels are placed on each cutter path. A faster turning center cutter assembly is provided in the form of (1) a single abrasion type tri-cone cutter driven by either a stationary frame mounted on the carrier, or (2) an inner cutter carrier occupying the center region immediately radially inwardly of the location of the last cutter path involving plural cutter wheels, with a single kerf forming disc cutter wheel located on each circular cutter path of the inner cutter carrier.

28 Claims, 6 Drawing Figures

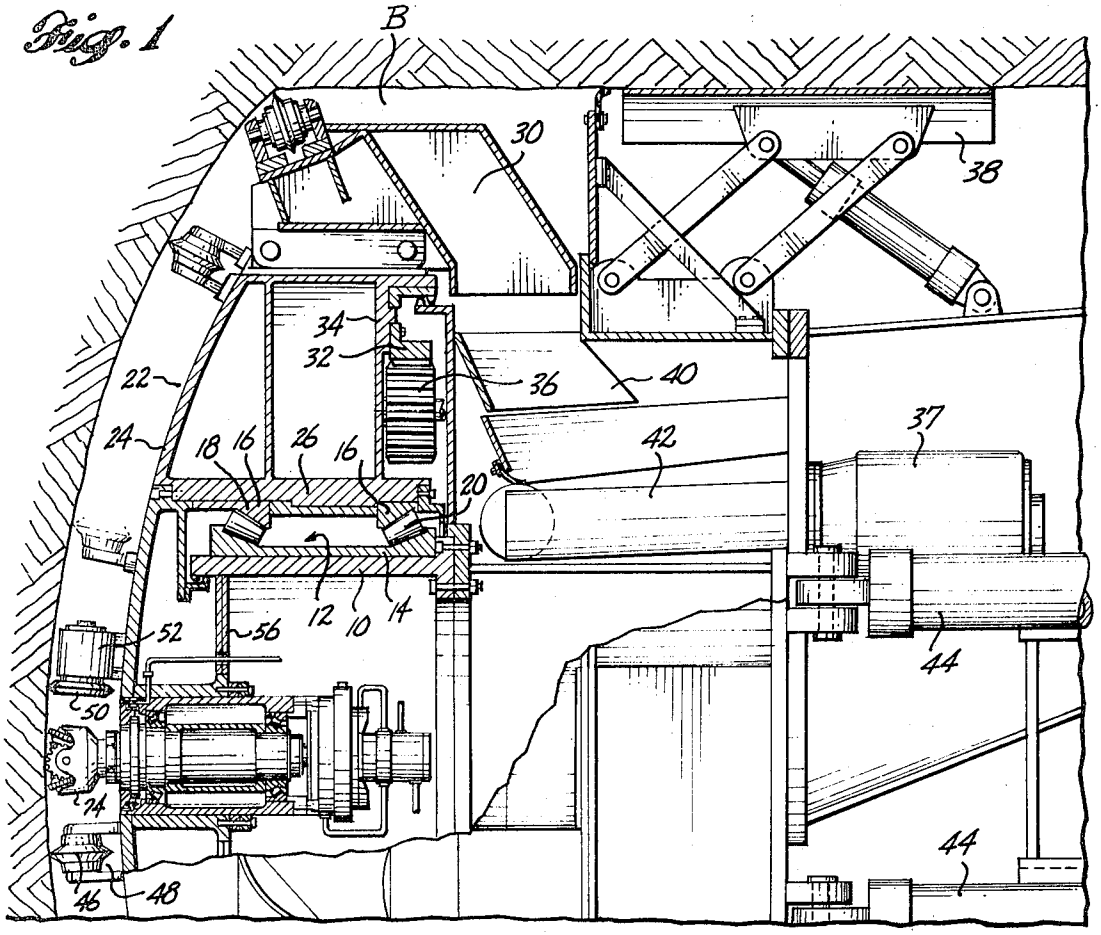


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Fig. 1



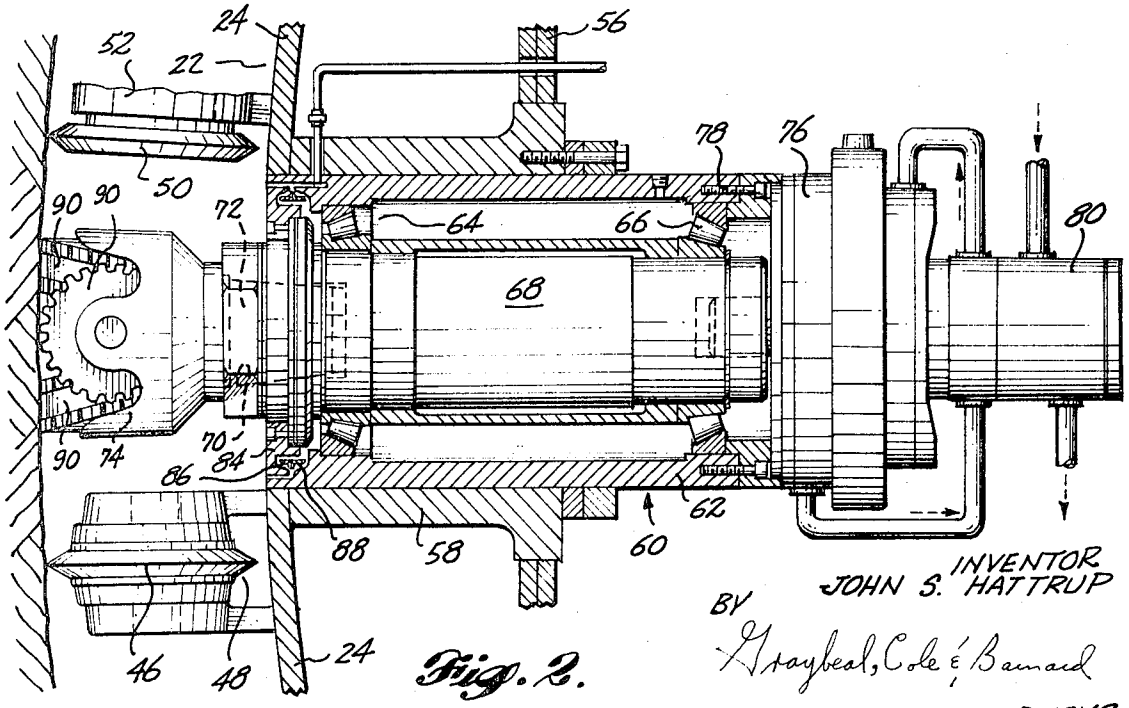


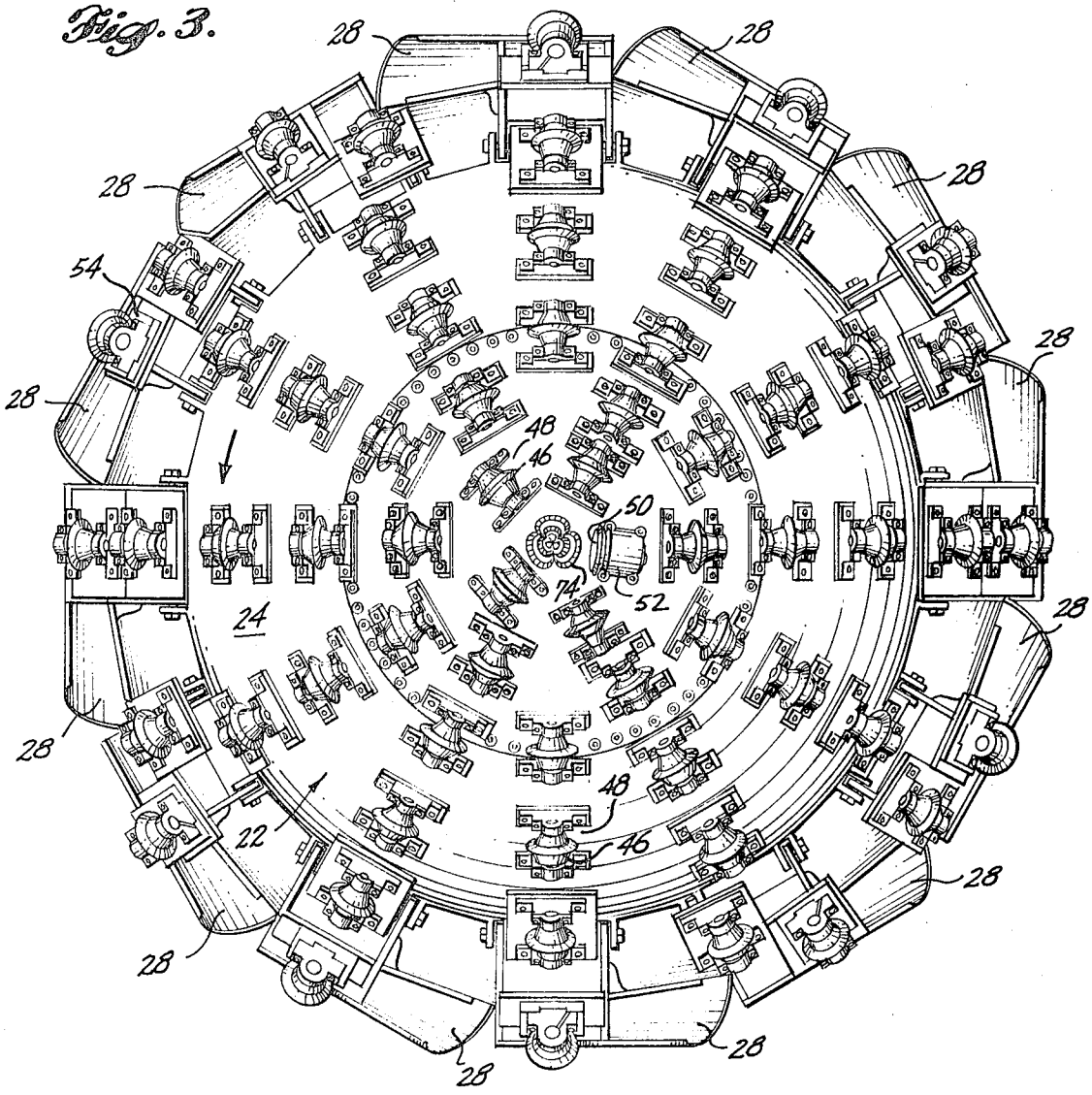
Fig. 2.

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Fig. 3.



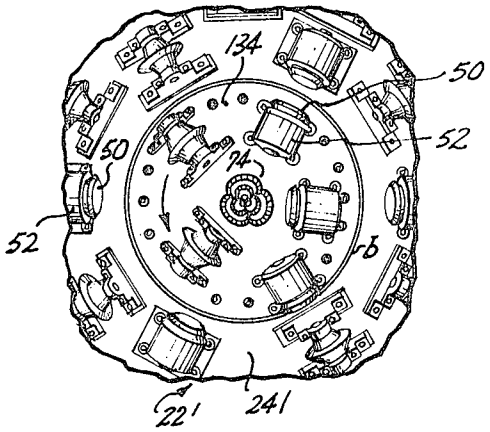


Fig. 6.

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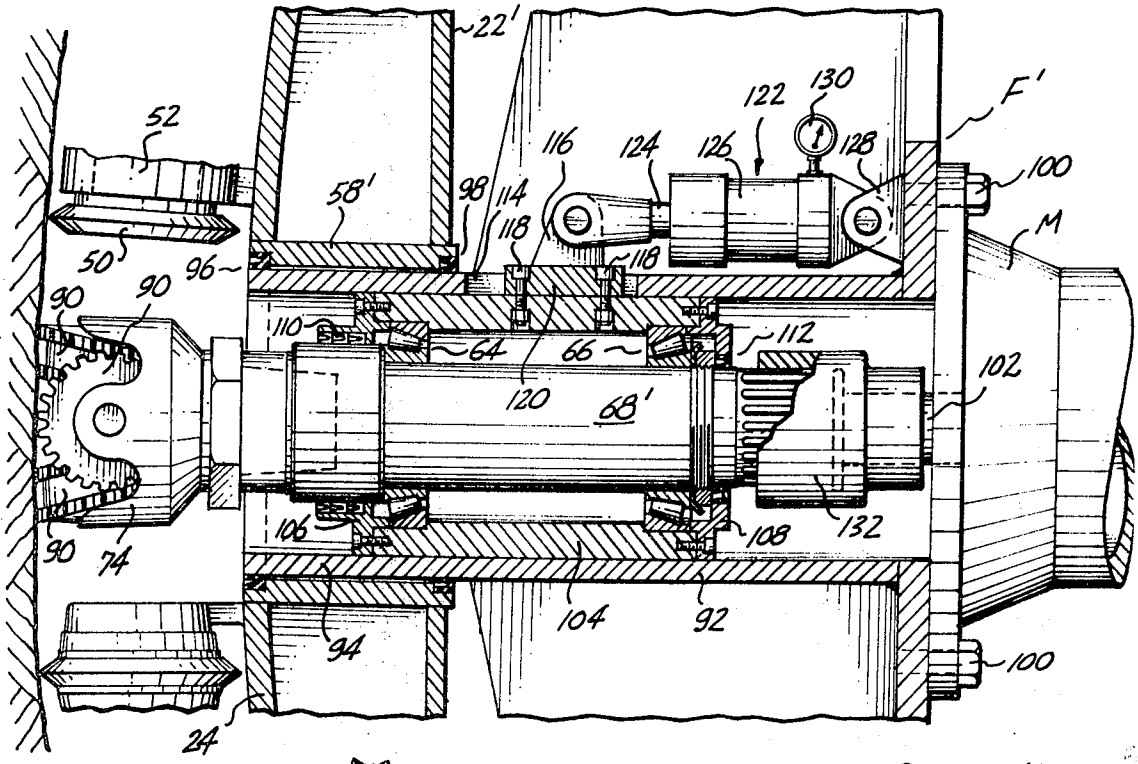


Fig. 4.

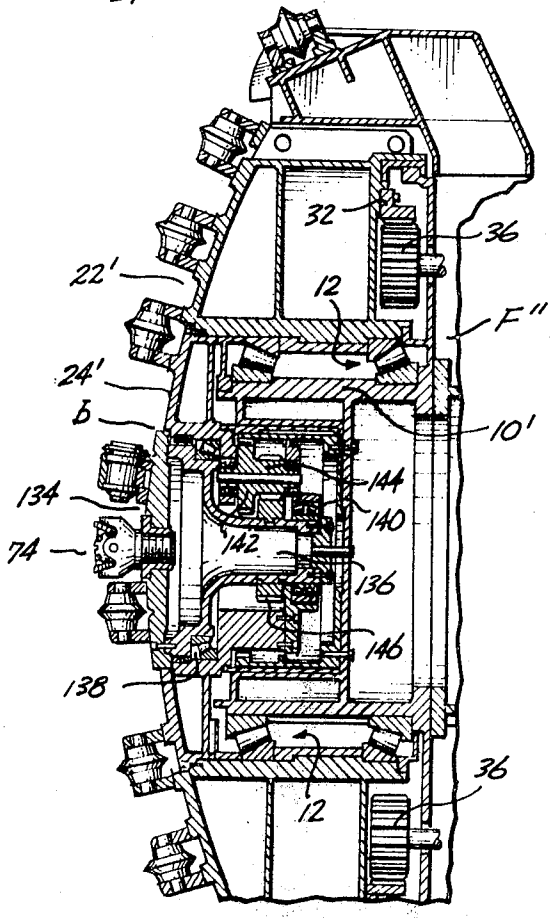


Fig. 5.

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ROLLER BUTTER ROCK BORING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to rock or hard earth formation boring, and more particularly to improved boring methods and machines for high rate boring.

2. Description of the Prior Art

Most existing boring machines comprise a single rotary cutterhead or carrier on which is placed a plurality of cutters, e.g., rolling disc cutters. The cutters are arranged to cut a plurality of concentrically arranged kerfs in the rock or other material being bored, with the usual practice being to locate a single cutter on each cutter path. The Richard J. Robbins et al. U.S. Pat. No. 3,232,670, granted Feb. 1, 1966, discloses this type of boring machine.

It is known to broadly divide a cutterhead into inner and outer parts, and to mount cutter elements on each of them and to rotate the parts at different speeds. However, the expressed reason for constructing cutterhead in this manner is to permit rotation of the inner and outer parts in opposite directions so that the torque exerted on the frame of the machine can be substantially balanced. Known machines of this type involve only a relatively small number of cutter elements in total, and only a single cutter element per each cutter path. Examples of boring machines of this type are shown by James S. Robbins U.S. Pat. No. 3,061,289, granted Oct. 30, 1962, and by Hoever U.S. Pat. No. 3,387,893, granted June 11, 1968.

It is also known to provide a boring machine with a large cutter carrier which carriers all of the cutter elements except for a single center cutter, which many comprise a tricone type drilling bit. However, in known installations this has been for the purpose of making it possible to advance the center cutter independently of the machine proper, for the purpose of forming a pilot hole. An example of a boring machine of this type is shown by the Lawrence et al. U.S. Pat. No. 3,386,520, granted June 4, 1968.

Morgan U.S. Pat. No. 1,674,870, granted June 26, 1928, discloses a boring machine having a cutterhead divided into a plurality of concentrically related parts, each of which is rotated at a different speed. All but the innermost cutterhead part involves a pair of oppositely directed drag bit carrying support arms. The innermost cutterhead part carries a single drag bit cutter. The described purpose of this arrangement is to permit the outer cutters to be rotated at a slower rate than the inner cutters. A single large electric motor located near the rear of the machine is used to drive all of the cutter carriers, with the speed differential being provided by a system of gearing. This type of boring machine is incapable of high boring rates in hard material.

SUMMARY OF THE INVENTION

The present invention relates to boring machines having a relatively large main cutter carrier on which is placed a large number of kerf forming disc cutters. According to the invention the cutter assemblies are spaced closely together both radially and angularly of the carrier, to provide both a relatively large number of closely spaced circular cutter paths, and plural cutters on at least most of the paths.

According to one form of the invention, an abrasion type center cutter is used and is adapted to be independently rotated with respect to the cutter carrier. The cutter carrier is rotated at a speed which provides effective utilization of the disc type cutters, and the center cutter is rotated at a speed necessary for long life operation of the abrasion type cutter. The cutter carrier, and the disc type cutters carried thereby, and the abrasion type center cutter are rotated at different angular velocities. However, they are rotated in the same direction and are advanced forwardly together at substantially the same rate of axial travel.

Another aspect of the invention involves a boring machine comprising inner and outer cutter carriers, each of which carries a plurality of cutter wheels. Each cutter wheel is mounted for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels. A plurality but equal number of cutter wheels is provided for each cutter wheel path on the outer carrier. The inner radial boundary of the outer cutter carrier and the outer radial boundary of the inner cutter carrier is located substantially immediately radially inwardly of the last circular zone of a size to accommodate more than one cutter wheel per cutter path, i.e., substantially immediately radially inwardly of where the angular space between angularly adjacent cutter assemblies is less than the width of a cutter assembly. The inner cutter carrier comprises a center cutter, e.g., an abrasion type tri-cone cutter, and a single cutter wheel on each of its circular cutter paths.

The present invention relates to improved boring methods involving the use of boring machines of this general type, and to boring machine improvements as well, as hereinafter discussed in more detail.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view, partially in section and partially in side elevation, of a fragmented portion of an earth boring machine which includes features of the present invention;

FIG. 2 is an enlarged scale view of the center cutter assembly shown by FIG. 1;

FIG. 3 is a front elevational view of the earth boring machine, showing the close radial and angular spacing of the roller type cutter assemblies, and showing an abrasion type tricone cutter at the center of the machine;

FIG. 4 is a view like FIG. 2, but of a modified form of center cutter assembly;

FIG. 5 is a reduced scale axial section view of a fragmented portion of another embodiment of the invention involving a further modified form of center cutter assembly; and

FIG. 6 is a fragmentary front elevational view of the machine of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 the boring machine is shown to comprise a frame F having a husky forwardly directed tubular housing portion **10**. A bearing assembly **12**, shown to comprise inner and outer bearing races **14**, **16** and front and rear rows **18**, **20** of tapered roller type combined thrust and radial bearing elements, serves to rotatably support an outer cutter carrier **22** on the tubular support housing **10**, for rotation thereabout.

The outer cutter carrier **22** is shown to include an annular cutter mounting wall **24**, and an annular box beam type support portion extending axially rearwardly of the wall **24**, and including a generally cylindrical support hub **26** as a major structural element thereof.

A plurality of buckets B are carried at the outer periphery of the cutter carrier **22**. Each bucket B includes a pickup scoop **28** and a chute **30**. The buckets B are of conventional construction and for this reason will not be described in greater detail.

A large ring gear **32** having radially inwardly directed teeth is secured to a radial rear wall **34** of cutter carrier **22**. A plurality of drive gears, one of which is designated **36**, mesh with ring gear **32** and serve to rotate the outer cutter carrier **22**. Gears **36** are driven by electric motors, one of which is shown by and designated **37** in FIG. **1**.

As shown by FIG. **1**, each gear **36** is located radially outwardly of the bearing assembly **12** and radially inwardly of the buckets B, and axially rearwardly of the rear wall **34** of outer cutter carrier **22**.

An adjustable roof support or shield **38**, per se forming no part of this invention, is shown mounted on the frame F rearwardly of the cutterhead region. The bucket chutes **30** are arranged to discharge into a funnel or collector **40** arranged to

deposit the cuttings and other material picked up by the buckets onto a take-out conveyor 42. The frame F, and the various functional components carried thereby, are moved forwardly by plurality of thrust rams, portions of two of which are shown in FIG. 1 and designated 44. By way of typical and therefore nonlimitive example, the mechanism for moving the boring machine forwardly may be of the type disclosed in detail by the Richard J. Robbins et al. U.S. Pat. No. 3,203,734, granted Aug. 31, 1965, the contents of which are hereby incorporated herein by this specific reference to such patent.

Referring to FIG. 3, a plurality of kerf forming disc cutters are mounted on the front wall 24 of the cutter carrier 22. For clarity of illustration, only some of the cutter assemblies are referenced. Most of the cutter assemblies include a cutter wheel 46 supported by a shaft which in turn is supported at both of its two ends. This type of cutter assembly is designated 48. Some of the cutter assemblies comprise a cutter wheel 50 which is of the overhung type, i.e., it is supported by a shaft which extends endwise on one side of the cutter only. This type of cutter assembly is designated 52. Reference is made to Gulfelt U.S. Pat. No. 2,915,291 for a showing of a manner of mounting cutters 52. A third type of cutter assembly is mounted on a hinged plate or base. This type of cutter assembly is termed a "gauge cutter assembly" and is designated 54. The cutter assemblies 48, and the bearing support and seals for cutters 52, may be of the type which are disclosed in detail in the Richard J. Robbins et al. U.S. Pat. No. 3,216,513, granted Nov. 9, 1965. The gauge cutter assemblies may be of the type shown by the Richard J. Robbins et al. U.S. Pat. No. 3,232,670, granted Feb. 1, 1966. All three of these identified patents are hereby expressly corporated herein, by this specific reference to such patents.

The front wall 24, and a radial wall 56 spaced rearwardly therefrom, both extend radially inwardly from hub 26 towards the center of rotation, and a smaller diameter hub 58. Hub 58 provides the cutter carrier 22 with an open center or socket in which is located the center cutter assembly 60. Cutter assembly 60 includes a tubular mount 62 which is snugly received within the inner hub 58. Mount 62 is secured to the hub 58, and hence is a rotational part of the cutter carrier 22. Front and rear bearing assemblies 64, 66, each shown to be of a type designed to carry both radial and axial loads, serve to mount a short drive shaft 68 for rotation within the tubular mount 62.

A box type tool joint 70 is provided at the forward end of shaft 68 to receive the pin type tool joint 72 of a tri-cone type cutter 74. A hydraulic motor 76 is firmly secured to the rear end of mount 62, such as by a plurality of bolts 78 extending through a portion of the motor housing into the rear end portion of the mount 62. Since the motor 76 is secured to, or fixed relative to, the mount 62, and since the mount 62 is a rotational part of the cutter carrier 22, the motor 76 rotates with the cutter carrier 22. By way of typical and therefore non-limitive example, the motor 76 may be of a hydraulic gear type. A stationary fluid supply and return manifold 80 is located rearwardly of the motor 76, and a swivel type distributor 82 is located between the motor 76 and manifold 80. The motor 76 includes a shaft 77 which is received in a socket 79 formed in the rear end of shaft 68. Shaft 77 is keyed, spline connected, or otherwise drivingly attached to the shaft 68.

The forward end of the tubular mount 62 is recessed to receive a seal assembly. An annular seal retainer 84 is bolted or otherwise secured to a forward end portion of shaft 68. A seal cavity is formed by and between the inner face of retainer plate 84 and radial and axial surface portions of the recess. Preferably, the seal is of the type shown by the aforementioned Richard J. Robbins et al. U.S. Pat. No. 3,216,513. It comprises a pair of seal members, one fixed and one rotating, having hardened material, (e.g., metal, ceramic or cermet) seal faces in tight contact with each other. As disclosed in such patent, resilient cushioning rings may be provided for maintaining the seal faces in tight contact with each other.

By way of typical and therefore non-limitive example, the abrasive action type center cutter may be of the general type shown by the Anderson D. White U.S. Pat. No. 3,401,759, issued Sept. 17, 1968. The contents of such patent are hereby incorporated herein by this specific reference.

In operation the cutter carrier 22 is rotated at a first angular velocity consistent with, or at least approaching, efficient and effective operation of the disc type cutters 46, 50. The center cutter 74 which is operated at a higher speed consistent with, or at least approaching, efficient and effective operation of the abrasive action type cutter bits 90 which make up the tri-cone cutter 74. In a typical installation the angular velocity of the cutter carrier 22 may be about 10 revolutions per minute, and the angular velocity of the center cutter 74 about 40 revolutions per minute.

According to the invention, the hydraulic motor 76 is used because it provides a simple yet effective way of varying the rotational speed of the center cutter 74, independently of the rotational speed of the cutter carrier 22.

Abrasive action type cutters, such as cutters 90, are designed to be rotated at a relatively fast angular velocity which is a variable dependent on the axial loading or thrust force experienced by the cutters. Use of the cutters outside of the design range of angular velocity results in a low cutter life. According to the invention, the rotational velocity or the cutter 74 is varied in accordance with the axial load or thrust forces experienced by the cutter elements 90. The machine shown by FIG. 4 if modified to include equipment measuring the thrust forces experienced by the center cutter 74. In this form the tubular mount 92 is a fixed part of the machine frame F'. The cutter carrier 22' is basically like cutter carrier 22, except that its inner hub 58' is mounted for rotation about the forward end portion 94 of the tubular mount 92. Annular seals 96, 98 are provided between the hub 58' and the forward end portion 94 of mount 92, preferably at the front and rear ends of the inner hub 58', as illustrated.

In this form of the invention the motor M is secured to the frame F', such as by plurality of bolts 100, and includes an output shaft 102 coaxially arranged with the center cutter shaft 68'. The motor may be a hydraulic motor, as before, or an electric motor.

An axially slidable sleeve 104 is rather snugly received within the intermediate portion of mount 92. The support bearing assemblies 64, 66 are contained within sleeve 104 and serve to mount the shaft 68' for rotation within sleeve 104. Front and rear retainer members 106, 108 are provided at the front and rear ends of sleeve 104, and seals 110, 112, respectively, are associated with the retainer members 106, 108.

An axially elongated slot 114 is formed in a wall portion of tubular mount 92. A laterally projecting ear 116 is suitably secured to the sleeve 104 in the vicinity of slot 114 (such as by bolts 118 extending through both the sleeve 104 and a base 120 connected to the ear 116). According to the invention, an instrument for measuring the thrust experienced by center cutter 74. The instrument may take the form of a pressure transducer 122 shown to comprise a piston 124 coupled at its outer end to the ear 116 and a cylinder 126 coupled at its outer end to a mounting ear 128 secured to the frame F'. A direct reading pressure gauge 130 is shown connected to the fluid chamber within the cylinder 126. The endwise force on cutter 74 is transmitted through the shaft 68', to the bearing assemblies 64, 66, then to the sleeve 104, then to the mounting ear 116, and then to the piston 124. The piston 124 exerts a pressure on the fluid inside cylinder 126 which is proportional to the force exerted on the cutter elements 90 by the earth material. Although the gauge 130 is shown in close proximity to the transducer 122, it is to be understood that such gauge is in practice located at or near the station of the operator responsible for varying the drive speed of the center cutter 74. It is also within the scope of this invention for the gauge 130 to be replaced by an automatic control system operable to automatically vary the drive speed of the center cutter 74 in accordance with the pressure measured in the transducer 122.

A splined type coupler 132, or the like, is provided between the forward end of output shaft 102 and the rear end of center cutter shaft 68', so that the shaft 68' can move axially somewhat without disturbing the rotational forces being transmitted to it by the shaft 102.

Two cutter carriers are provided in the embodiment of FIG. 5, an annular outer carrier 22' and a circular inner carrier 134. The radial boundary between the carriers 22', 134 is designated *b* in FIGS. 5 and 6. It is substantially immediately radially inwardly of where the angular space on carrier 22' between angularly adjacent cutter assemblies is less than the width of a cutter assembly, i.e., substantially immediately radially inwardly of the last circular zone of a size to permit placement of plural cutter wheels on each cutter path.

As shown by FIGS. 3 and 6, the outer cutter carrier 22' carries two cutter wheels per cutter path. The inner carrier 134 carries only one cutter wheel per cutter path, in combination with the center cutter 74. In this form of the invention the outer carrier 22' is motor driven through gears 36, 32, and a planetary drive train, housed within the forward tubular portion 10' of frame F'', drivenly connects the outer carrier 22' to the inner carrier 134. The inner carrier 134 is provided with a shaft 136 which is forwardly supported by a bearing assembly 138 and rearwardly supported by a bearing assembly 140. Bearing 138 is of a combined radial thrust type and is positioned between forward parts of the two carriers 22', 134. A plurality (e.g., three) of gears 142 are carried by the outer cutter carrier 22'. The gears 142 are connected to smaller diameter gears 144 which in turn mesh with a gear 146 secured to shaft 136. Hence, the gearing 142, 144, 146 form a speed increasing transmission. Preferably, the inner carrier 134 is driven at a rotational velocity somewhere between twice the annular velocity of the outer carrier 22' and the optimum velocity for optimum utilization of center cutter 74.

What is claimed is:

1. An earth boring machine comprising:
a rotary cutter carrier having an open center;
a plurality of cutter assemblies on said carrier spaced radially and angularly apart, each said cutter assembly comprising a kerf forming disc cutter wheel and mounting means mounting said cutter wheel for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels, with the innermost said cutter assembly placing its cutter wheel closely adjacent the outer boundary of said open center;
a rotary shaft in said open center having tool joint means at its forward end;
a relatively high speed center zone cutter having a mounting portion including tool joint means connected to the tool joint means of said shaft, and a cutting portion including abrasion type cutter means substantially filling the circular center zone inwardly of said innermost cutter wheel and axially forwardly of said shaft, said cutting portion sweeping a path during use which has a forward boundary that is substantially even with the forward boundary of the cutting path traveled by said innermost cutter assembly;
means for rotating said cutter carrier at the angular velocity necessary for effective operation of said disc cutter wheels;
means for rotating said shaft and said center zone cutter at a faster angular velocity necessary for effective operation of said abrasion type cutter means; and
means for moving said boring machine axially forwardly, with the cutter wheels and the center zone cutter advancing axially together at substantially the same rate.

2. The earth boring machine of claim 1, wherein said cutter carrier has a central tubular hub portion, the interior of which forms said open center, and said shaft is journaled for rotation within said hub portion, and said boring machine further comprises seal means between said shaft and said hub portion near the forward end of said open center.

3. The earth boring machine of claim 2, wherein said seal means comprises a first hard material seal element carried by said hub and having a forwardly directed seal face, and a second hard material seal element carried by said shaft and having a rearwardly directed seal face in tight contact with the seal face of said first seal element, with both of said seal elements being annular and both surrounding said shaft.

4. The earth boring machine of claim 1, wherein at least the innermost cutter assembly includes a cutter wheel located closely adjacent the radially outer boundary of the center zone cutter.

5. An earth boring machine comprising:
a rotary cutter carrier having an open center;
a plurality of cutter assemblies on said carrier spaced radially and angularly apart, each said cutter assembly comprising a kerf forming disc cutter wheel and mounting means mounting said cutter wheel for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels, with the innermost said cutter assembly placing its cutter wheel closely adjacent the outer boundary of said open center, said cutter carrier having a central tubular hub portion, the interior of which forms said open center;
a rotary shaft in said open center having tool joint means at its forward end, said shaft being journaled for rotation within said hub portion;
a relatively high speed center zone cutter having a mounting portion including tool joint means connected to the tool joint means of said shaft, and a cutting portion including abrasion type cutter means substantially filling the circular center zone inwardly of said innermost cutter wheel and axially forwardly of said shaft;
means for rotating said cutter carrier at the angular velocity necessary for effective operation of said disc cutter wheels;
a motor mount carried by and rotated with the cutter carrier;
means for rotating said shaft and said center zone cutter at a faster angular velocity necessary for effective operation of said abrasion type cutter means, said means comprising a motor means drivingly connected to said rotary shaft, including a housing which is secured to and rotates with said motor mount; and
means for moving said boring machine axially forwardly, with the cutter wheels and the center zone cutter advancing axially together at substantially the same rate.

6. The earth boring machine of claim 5, wherein said motor is a fluid motor having a supply port and said machine includes a stationary fluid supply conduit, and swivel coupler means interconnected between said stationary supply conduit and the supply and port of said motor.

7. The earth boring machine of claim 5, wherein said motor mount comprises an elongated tubular member at least the forward portion of which is located inside said tubular hub, said rotary shaft is housed within said tubular member and bearing means are located radially between said shaft and said tubular member, with said motor means being removably secured to a rear portion of said tubular member, and said motor means having an output shaft coaxially related to and coupled to said rotary shaft.

8. The earth boring machine of claim 7, wherein said boring machine further comprises seal means between said shaft and said hub portion, said seal means comprising a first seal element carried by said hub and having a seal face of hard material, and a second seal element carried by said shaft and having a seal face of a second hard in tight contact with the seal face of said first seal element, with both of said seal elements being annular and both surrounding said shaft.

9. An earth boring machine comprising:
a rotary cutter carrier having an open center;
a plurality of cutter assemblies on said carrier spaced radially and angularly apart, each said cutter assembly comprising a kerf forming disc cutter wheel and mounting

means mounting said cutter wheel for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels, with the innermost said cutter assembly placing its cutter wheel closely adjacent the outer boundary of said open center, said cutter carrier having a central tubular hub portion, the interior of which forms said open center;

a rotary shaft in said open center having tool joint means at its forward end;

a relatively high speed center zone cutter having a mounting portion including tool joint means connected to the tool joint means of said shaft, and a cutting portion including abrasion type cutter means substantially filling the circular center zone inwardly of said innermost cutter wheel and axially forwardly of said shaft;

said machine also including a cutterhead support frame, a tubular support member having a rearward portion secured to said support frame and a forward portion which projects forwardly into said open center, with said rotary shaft being journaled for rotation within said tubular support member;

means for rotating said cutter carrier at the angular velocity necessary for effective operation of said disc cutter wheels;

means for rotating said shaft and said center zone cutter at a faster angular velocity necessary for effective operation of said abrasion type cutter means, said means comprising motor means secured to said support frame, and means drivingly interconnecting the motor means and said rotary shaft; and

means for moving said boring machine axially forwardly, with the cutter wheels and the center zone cutter advancing axially together at substantially the same rate.

10. The earth boring machine of claim 9, wherein an axially movable support sleeve is located inside of said tubular support member, said rotary shaft is rotatably supported in said support sleeve and is axially movable therewith, said motor means includes an output shaft and a spline connected to said rotary shaft, and said machine further includes transducer means interconnected between said movable sleeve and a portion of said support frame, for both limiting axial movement of said rotary shaft and measuring the thrust forces imposed on the center zone cutter by the material being bored.

11. An improved method of boring hard rock or earth formations comprising:

providing a rotatable carrier with a plurality of kerf forming disc cutter wheels in sufficient numbers to result in contiguous radial and circumferential spacing of such cutter wheels over the full extent of the carrier;

mounting the cutter wheels on said carrier, each with its forward cutting boundary substantially on a common radially continuous cutting face with the forward cutting boundary of each adjacent cutter wheel;

mounting each cutter wheel for both free rotation about its axis and rolling travel along a circular path concentrically related to both the paths of the other cutter wheels and the axis of rotation of said carrier;

locating an abrasion type cutter at the center of said carrier to rotate in a path having a forward boundary that is substantially even with the forward boundary of the path traveled by at least the innermost cutter wheel; and

moving said carrier, the cutter wheels thereon, and said abrasion type cutter axially forwardly at substantially the same rate of travel while rotating said cutter carrier at an angular velocity necessary for effective operation of said disc cutter wheels, and rotating said abrasion type cutter at a faster angular velocity necessary for effective operation of said abrasion type cutter means.

12. The method of claim 11, further comprising sensing the axial thrust forces on said abrasion type cutter and changing the angular velocity of said cutter in response to a change in the thrust force, towards a more efficient operation of said cutter.

13. An earth boring machine comprising:

an inner rotary cutter carrier;

an annular outer rotary cutter carrier concentrically surrounding said inner carrier;

a plurality of cutter assemblies on each carrier spaced both radially and angularly apart, each said cutter assembly comprising a cutter wheel and mounting means mounting the cutter wheel for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels, with the distance between adjacent cutter wheel paths being less than the radial length of a cutter assembly, with the cutter assemblies on the outer carrier placing a plurality but equal number of cutter wheels on each outer carrier cutter wheel path, with the inner radial boundary of the outer cutter carrier and the outer radial boundary of the inner cutter carrier being substantially immediately radially inwardly of where the angular space between angularly adjacent cutter assemblies is less than the width of a cutter assembly, and wherein the cutter assemblies on the inner carrier place a single cutter on each inner carrier cutter wheel path;

means for rotating the outer cutter carrier at a predetermined angular velocity; and

means for rotating the inner cutter carrier at a substantially faster angular velocity.

14. An earth boring machine according to claim 13, wherein at least the innermost cutter assembly on the outer carrier, and at least the outermost cutter assembly on the inner carrier, each comprises mounting means located wholly on the side of its cutter wheel directed away from the boundary between the two carriers.

15. An earth boring machine according to claim 13, wherein the innermost cutter assemblies on the outer carrier, and the outermost assembly on the inner carrier, each comprises an exposed full side face located closely adjacent the boundary between the inner and outer carriers.

16. An earth boring machine according to claim 13, further comprising a fixed support, bearing means mounting the outer cutter carrier on said support, for rotation thereabout, and bearing means between said inner and outer cutter carrier, whereby said inner carrier is supported by said outer carrier.

17. An earth boring machine according to claim 16, wherein said fixed support is tubular and a speed increasing planetary gear means is housed within the forward portion thereof, and said gearing drivenly connects the outer carrier to the inner carrier, and drive means for directly driving the outer carrier.

18. In an earth boring operation, a method of arranging and utilizing roller cutters, comprising:

mounting a plurality of roller cutters on each of an inner rotary cutter carrier and an annular outer rotor cutter carrier concentrically surrounding said inner carrier;

on each cutter carrier spacing the roller cutters both radially and angularly apart;

on each cutter carrier mounting each roller cutter for both free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the outer cutter wheels;

on each cutter carrier radially spacing the roller cutters relatively close together so that the distance between adjacent cutter paths is less than the combined radial length of a cutter and its mounting means;

on the outer cutter carrier placing a predetermined plurality but equal number of roller cutters on each cutter wheel path;

locating the inner radial boundary of the outer cutter carrier, and the outer radial boundary of the inner cutter carrier, substantially immediately radially inwardly of the smallest circular path on to which space availability on the outer carrier will permit the placement of said predetermined plural number of roller cutters;

on the inner carrier placing a single cutter wheel on each inner carrier cutter wheel path;

rotating the outer cutter carrier at a predetermined angular velocity; and

rotating the inner cutter carrier at a substantially faster angular velocity.

19. An earth boring machine comprising:

a rotary cutter carrier including an inner zone and an annular outer zone concentrically surrounding said inner carrier;

a plurality of cutter assemblies in each said zone spaced both radially and angularly apart, each said cutter assembly comprising a cutter wheel and mounting means mounting the cutter wheel for free rotation about its axis and rolling travel along a circular path concentrically related to the paths of the other cutter wheels, with the distance between adjacent cutter wheel paths being less than the radial length of a cutter assembly, with the cutter assemblies in the outer zone placing a plurality but equal number of cutter wheels on each outer carrier cutter wheel path, with the inner radial boundary of the outer zone and the outer radial boundary of the inner zone being substantially immediately radially inwardly of where the angular space between angularly adjacent cutter assemblies is less than the width of a cutter assembly, and with the cutter assemblies in the inner zone placing a single cutter on each cutter wheel path of the inner zone;

a center zone cutter mounted for independent rotation at the center of said cutter carrier, said cutter being of a type which requires a relatively high rotational velocity for effective utilization and long life;

means for advancing both the cutter carrier, and the cutter wheels carried thereby, and the center zone cutter, axially forwardly into the material being bored;

means for rotating the cutter carrier at an angular velocity necessary for effective operation of the cutter wheels; and

means for rotating the inner cutter carrier at a substantially faster angular velocity necessary for effective operation of said center zone cutter.

20. The earth boring machine of claim 19, wherein said cutter carrier has a central tubular hub portion, and said center zone cutter is at the forward end of a shaft journaled for rotation within said hub portion, and said boring machine further comprises seal means between said shaft and said hub portion comprising a first seal element carried by said hub having a hard material seal face, and a second seal element carried by said shaft and having a hard material seal face in tight contact with the seal face of said first seal element.

21. The earth boring machine of claim 19, wherein at least the innermost cutter assembly includes an overhung cutter wheel located radially inwardly of its mounting means, and closely adjacent the radially outer boundary of the center zone cutter.

22. The earth boring machine of claim 19, wherein said cutter carrier has a central tubular hub portion, and said center zone cutter is at the forward end of a shaft journaled for rotation within said hub portion, and said boring machine also comprises a motor mount carried by and rotated with the cutter carrier, and motor means drivenly connected to said rotary shaft, said motor means including a housing which is secured to and rotates with said motor mount.

23. The earth boring machine of claim 22, wherein said motor is a fluid motor having a supply port and said machine includes a stationary fluid supply conduit, and swivel coupler means interconnected between said stationary supply conduit and the supply and port of said motor.

24. The earth boring machine of claim 22, wherein said motor mount comprises an elongated tubular member at least the forward portion of which is located inside said tubular hub, said rotary shaft is housed within said tubular member and bearing means are located radially between said shaft and said tubular member, with said motor means being removably secured to a rear portion of said tubular member, and said motor means having an output shaft coaxially related to and coupled to said rotary shaft.

25. The earth boring machine of claim 19, wherein said cutter carrier has a central tubular hub portion, the center zone cutter is at the forward end of a short shaft, and said machine includes a cutterhead support frame, a tubular support member having a rearward portion secured to said support frame and a forward portion which projects forwardly into said open center, with said shaft being journaled for rotation within said tubular support member, motor means carried at the rear of said tubular support member, and means drivenly interconnecting the motor means and said shaft.

26. An earth boring machine comprising a frame having a forwardly directed tubular portion of relatively large diameter;

a cutter carrier having an annular support portion positioned concentrically surrounding said tubular portion of the frame, and a generally radial forward cutter carrying part portion forwardly of, and extending both radially inwardly and radially outwardly from, the forward end of the tubular portion of said frame, and having an open center; a plurality of roller type cutters mounted on said cutter carrying part;

bearing means located radially between said tubular frame portion and the annular support portion of the cutter carrier, and serving to rotatably mount the cutter carrier onto said tubular housing, for rotation thereabout; and

an inner cutter assembly in the open center of said cutter carrier, said inner cutter assembly including a short drive shaft journaled in the tubular forward portion of the frame for rotation about an axis coincident with the axis of rotation of the cutter carrier, forwardly directed cutter means at its forward end, and drive means contained wholly within said tubular portion of the frame, for rotating the inner cutter carrier at a higher angular velocity than the outer cutter carrier.

27. The earth boring machine of claim 26, wherein said drive means comprises a system of speed increasing gears interconnected between a radially inner portion of the cutter carrier and said drive shaft, and means for rotatively driving said cutter carrier with it in turn driving said drive shaft through the intermediacy of said system of gears.

28. The earth boring machine of claim 26, wherein the drive means for the drive shaft is a motor which is at least partially housed within the tubular housing portion of the frame and includes an output shaft which is drivenly connected to said drive shaft.

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