This invention relates to well drilling tools and relates more particularly to a rotary rock bit. A general object of this invention is to provide a practical dependable bit for use in the rotary method of well drilling, that embodies novel and very effective cutter mounting means.

Another object of this invention is to provide a well bit of the character mentioned in which the two sets of transverse cutters or inner cutters are rotatably supported by a single pin directly supported at its ends and at its intermediate portion by integral parts of the bit body.

Another object of this invention is to provide an improved anti-friction bearing means for rotatably mounting the cutters of a well bit in which the balls or anti-friction member have extensive cooperation with the inner races whereby the wear and the forces are evenly distributed over large areas of the races affecting a marked reduction in the intensity of the pressures between the balls and the race surfaces.

Another object of this invention is to provide a rock bit in which each roller cutter is supported by axially spaced rows of balls each row of balls assuming end thrusts in both directions, as well as a radial thrusts.

Another object of this invention is to provide a rock bit in which the cutter supporting elements or pins have direct force-transmitting cooperation with the bit body thus eliminating relative play and wear between the parts and removing practically all of the stresses from the welds which tie the thrust washers to the body.

Another object of this invention is to provide a rock bit of the character mentioned embodying novel means for preventing relative rotation between the inner races of the cutter supporting bearings.

A further object of this invention is to provide novel nozzle elements or flow-beans that may be easily and quickly replaced to adapt the bit for use under various operating conditions.

The various objects and features of our invention will be fully understood from the following detailed description of a typical preferred form and application of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a vertical detailed sectional view of the bit provided by this invention illustrating the outer cutters and their mounting means. Fig. 2 is an enlarged, fragmentary vertical detailed sectional view illustrating the anti-friction mounting means of one of the outer cutters. Fig. 3 is an end elevation of a race member embodied in one of the outer cutter mounting means. Fig. 4 is a vertical detailed sectional view of the bit with the upper portion in elevation illustrating the mounting means of the inner cutters. Fig. 5 is an enlarged fragmentary vertical detailed sectional view illustrating the mounting means of one set of the inner cutters and Fig. 6 is an end elevation of a race member of one of the inner cutter bearings.

The improved rotary rock bit of the present invention includes, generally, a body 10, outer roller cutters 11, anti-friction bearing means 12 rotatably mounting the outer cutter 11 on the lower end of the body 10, sets of inner roller cutters 13 and 14, anti-friction bearing means 15 for rotatably mounting the sets of inner cutters 13 and 14 on the lower end of the body 10 and means 16 for directing the circulation fluid against the cutters 11, 13 and 14.

The body 10 is adapted to be connected with the lower end of a well drilling string and is shaped to carry the cutters 11, 13 and 14 and their bearing means. Means is provided at the upper end of the body 10 to facilitate its connection with the well drilling string. In the case illustrated, a tapered screw threaded pin 17 is provided on the upper end of the body 10 to connect with a threaded member of the drilling string.

A circulation passage 18 enters the body 10 from the upper end of its pin 17 to deliver the circulation fluid to the nozzle means 16. In accordance with the invention sets or pairs of legs 19 and 20 project from the lower end of the body 10. The legs 19 and 20 are integral parts of the body. The legs 19 are diametrically opposite and project outwardly as well as downwardly from the lower end of the body. There are two diametrically opposite legs 19 and the inner sides of the legs 19 are inclined downwardly and outwardly with respect to the vertical axis of the bit.

Raised bearing faces 21 are provided on the inner sides of the legs 19 adjacent their lower ends. The legs 20 are diametrically opposite and are spaced substantially 90° from the legs 19. The inner and outer sides of the principal or lower portions of the legs 20 are substantially vertical. Raised bearing faces 22 are provided on the outer sides of the legs 20 adjacent the lower ends of the legs.

The body 10 further includes a substantially central web 23 projecting downwardly within the series of legs 19 and 20. The web 23 is an integral part of the body 10. Cylindrical bosses 24 project transversely or horizontally from the web 23 adjacent the lower end of the web. The bosses...
project outwardly or radially in the direction of the legs 30 and raised faces 25 are provided at the bases or inner ends of the boxes 24. The web 23 is of substantial width in the direction of the legs 19 to have ample strength. Downwardly and outwardly projecting wings 26 are provided on the widened portion of the web 23 and oppose and are in substantial parallelism with the legs 19. Raised bearing faces 27 are provided on the outer sides of the wings 26, to oppose the bearing faces 21 of the legs.

The outer cutters 11 are provided to cut the web bore to gauge and to act on the outer portion of the bore at its lower wall. The cutters 11 are in the nature of slightly tapered or frustoconical roller cutters. There are two roller cutters, 11, one being arranged between each pair of opposing legs 19 and wings 26 to project downwardly beyond the lower ends of the legs 19 and wings 26. The cutters 11 have flat parallel ends and central longitudinal openings 28. Peripheral cutting teeth 29 are provided on the cutters 11. The active edges of the teeth 29 taper or converge inwardly toward the center of the longitu- dinal axis of the bit. The outer cutters of the depend- ing teeth 29 are bevelled off to be substantially vertical when the teeth come into contact with the formation at the bottom of the bore.

The means 12 for rotatably supporting the outer cutters 11 are in the nature of anti-fric- tion bearing means supporting the cutters for rotation about downwardly and inwardly inclined axes. Each bearing means 12 includes a supporting screw or pin 30. The pins 30 are passed outwardly through openings 31 in the wings 26 and their outer portions are threaded in openings 32 in the legs 19. The longitudinal axes of the openings 31 and 32 are inclined downwardly and inwardly with respect to the vertical axis of the bit. Heads 33 are provided on the inner ends of the pins 30 to engage outwardly against the wings 26. The heads 33 may be of the socket type to receive tools for threading the pins 30. The pins 30 may be secured or locked in place in any suitable manner.

The bearing means 12 further include thrust washers 34 surrounding the pins 30 and bearing outwardly against the faces 21 of the legs 19 and thrust washers 35 surrounding the pins 30 and bearing inwardly against the faces 27 of the wings 26. Outwardly projecting lugs 38 are provided on the outer thrust washers 34 and are disposed at the lower ends of the legs 19. Similar lugs 38 are provided on the inner thrust washer 35 and protect inwardly at the lower ends of the wings 26. A race member 38 surrounds each supporting pin 30 between the adjacent thrust washers 34 and 35. The thrust washers 34 and 35 are received in the opposite end portions of the cutter openings 26 and the race members 38 are entirely within the cutter openings substantially intermediate their ends.

The means 12 are in the nature of ball bearing means and races or ball grooves are provided in the axial direction of the lugs 38 and in the adjacent end portions of the washers 34 and 35 and the race members 38. Two axially spaced ball races or grooves 39 and 40 are provided in the wall of each cutter opening 26. The grooves 39 and 40 are spaced inwardly from the ends of the cutters 11 and are spaced a suitable distance apart. In accordance with the invention the grooves 39 and 40 are partially cylindrical in transverse cross section and are of substantial depth. The circumferential center lines of the grooves 39 lie in the same planes as the contacting or abutting ends of the outer thrust washers 34 and the outer ends of the race members 38. In a like manner the circumferential center lines of the grooves 40 in the same planes as the abutting end surfaces of the inner washers 35 and the race members 38.

Partial grooves are provided in the inner corners of the outer thrust washers 34 and the outer corners of the race members 38 and these partial grooves join or register to form ball channels or grooves 41. The grooves 41 formed in the adjacent corners of the washers 34 and members 38 occur at the split or plane of abutment of the washers and members. The outer thrust washers 34 are considerably larger in diameter than the race members 38 and because of this relationship the grooves 41 have their greater portions in the washers 34. Annular series of balls 42 cooperate with the opposing grooves 39 and 41. The balls 42 cooperating with the deep grooves 39 in the cutters 11 and the deep and partially offset grooves 41 effectively transmit radial thrusts and the heavy outwardly directed end thrusts. The partial grooves 40 cooperating with them are also operable to transmit inward end thrusts between the cutters 11 and the inner elements of the bearings.

Ball races or grooves 43 are provided in the inner thrust washers 35 and the race members 38 at their abutting ends. Partial grooves are provided in the inner corners of the race members 38 and partial grooves are provided in the outer corners of the washers 35 and these partial grooves join or register to form the grooves 43. The grooves 43 oppose the inner interiors of the cutters 11. The washers 35 are larger in diameter than the race members 38 and the grooves 43 have their greatest portions in the thrust washers 35. Annular series of balls 44 cooperate with the opposing grooves 40 and 43. The balls 44 are particularly effective in the transmission of the inwardly directing end thrusts between the cutters 11 and the inner bearing parts. The grooves 40 and the grooves 43 are of such depth that the balls 44 transmit end thrusts in both directions and the radial thrusts between the cutters 11 and the inner bearing elements. It is to be understood that the spaced series of balls 42 and 44 serve to rotatably support the cutters 11 and that the walls of the cutter openings 26 have proper working clearance with the peripheries of the thrust washers 34 and 38.

Means are provided to prevent rotation of the thrust washers 34 and 35 and the race members 38. The lugs 36 of the washers 34 are secured to the lower ends of the legs 19 by welds 45. In a like manner the lugs 37 of the washers 35 are secured to the lower ends of the wings 26 by welds 46. The race members 38 have axial openings 47 spaced between their interiors and their peripheries. The thrust washers 34 and 35 are provided with axially extending sockets 48 which are the end to flange with the openings 47. Dowel pins 49 extend through the openings 47 and project into the sockets 48. The welds 45 and 46 serve to prevent rotation of the washers 34 and 35, respectively, and the pins 49 operate to prevent rotation of the race members 38.

In assembling an outer cutter 11 on the body 10 the series of balls 42 is arranged in the outer cutter groove 39 and the outer washer 34 is then arranged in the outer portion of the opening 26 to engage against the balls 42. The race mem-
ber 38 is then inserted in the cutter opening 28 to engage against the balls 42. The balls 44 are then inserted into the notch 50 one at a time. The notch 50 is provided in each race member 38 at its inner end to communicate with the groove 43. In assembling the balls 44 in the groove 40 and the portion of the groove 43 in the race member 38 the balls are passed through the notch 50 one at a time. The notch 50 makes it possible to introduce the balls 44 in the deep groove 40 and the portion of the groove 43 in the race member 38. The dowel pin 49 may be carried by the race member 38 to have one end introduced into the socket 48 of the outer washer 34 when the race member is positioned in the opening 28. Following the introduction of the balls 44 in the groove 40 the inner thrust washer 35 is positioned in the opening 28 to engage against the balls 44. The projecting inner portion of the dowel pin 49 is received in the socket 48 which serves to carry the balls when the washer is arranged in place. The assembly of the cutter 11 and its bearing elements is introduced between a leg 19 and a wing 26 and the supporting pin 30 is passed outwardly through the opening 31 and the bearing elements to have their inner ends abutted 32. The lug 36 and the lug 37 may then be welded to the leg 19 and the wing 26, respectively.

The inner cutters 13 and 14 are provided to act on the earth formation at the inner portion of the well bore and are supported on the body 16 through the bearing means 15 to rotate about a common substantially horizontal axis. The cutters 13 and 14 are in the nature of roller cutters, the cutters 13 being frusto-conical and the cutters 14 being generally cylindrical. The cutters 13 are considerably longer and larger in diameter than the cutters 14. The cutters 13 preferably have concave outer ends and flat inner ends. A central longitudinal opening 51 is provided in each cutter 13. The outer portions of the cutter openings 51 are enlarged in diameter. The cutters 13 are provided with peripheral cutting teeth 52. The teeth 52 may be notched, as illustrated in the drawings, and their active edges are inwardly convergent with respect to the central longitudinal axis of the bit. The cutters 14 have flat parallel ends and central longitudinal openings 53. Axially extending cutters 54 are provided on the cutters 14. The active edges of the teeth 54 may be notched and are substantially horizontal. The means 15 for rotatably supporting the cutters 13 and 14 is a feature of the invention. In accordance with the invention the cutter mounting means 15 includes a single support member 55 which serves to carry both sets of cutters 13 and 14 and their bearing elements. The pin 55 is substantially horizontal or transverse to the vertical axis of the body 16 and extends between the two legs 20. The pin 55 is passed inwardly through an opening in one leg 20, extends through a transverse opening 57 in the web 23 and has an end portion threaded in an opening 58 in the other body leg 20. The pin 55 arranged in this manner has its opposite end portions supported in openings in the body legs 20 and its intermediate portion supported in the opening 57 of the body web 23. A head 59 is provided on the pin 55 and is received in the opening 57. The cutter supporting means 55 may be locked against unthreading in any suitable manner. The pairs of cutters 13 and 14 are arranged between the legs 20 and the web 23 and the pin 55 passes through the openings of the several cutters. The cutters 13 are positioned adjacent the inner sides of the legs 20 and the cutters 14 are located between the cutters 13 and the body web 23. The bearing means 15 includes or provides a plurality of axially spaced races or grooves in each cutter 13. In the illustration there are three axially spaced grooves 60, 61 and 62 in the inner of each cutter 13. The grooves 60, 61 and 62 are partially cylindrical in transverse cross section and are of substantial depth. The grooves 62 occur at the lines of junction of the enlarged outer portions of the cutter openings 51 and the major portions of the openings and are pitched or faced outwardly somewhat toward the legs 20. The bearing means 15 further include a series of race members 63, 64 and 65 in each cutter 13 and thrust washers 66 bearing against the faces 22 of the legs 20 and received in the enlarged outer portions of the cutter openings 51. The members 63, 64 and 65 are cylindrical and of the same diameter. The inner ends of the inner members 63 lie in the same planes as the inner ends of the cutters 13. The abutting members 64 and 65 are in the same planes as the circumferential centers of the grooves 60 and the abutting ends of the members 64 and 65 are in the same planes as the circumferential centers of the grooves 61.

Races or grooves 67 are provided in the peripheries of the race members 63 and 64 at their abutting ends and similar grooves 68 are provided in the peripheries of the members 64 and 65 at their abutting ends. The grooves 67 have portions in the members 63 and 64 which are substantially horizontal and are diametrically opposite each other. The grooves 68 lie in the same planes as the abutting ends of the members 64 and 65. The grooves 67 and 68 are of substantial depth having an arc or curvature of approximately 180°. The grooves 67 directly oppose the grooves 68 and are diametrically opposite the grooves 67. Annular series of balls 70 are arranged in the opposing grooves 60 and 67 and annular series of balls 71 are arranged in the opposing grooves 61 and 68. Due to the depth of the grooves receiving them the balls 70 and 71 are out of the grooves 60 and 67 and radial thrusts and end thrusts in both directions between the cutters 13 and the inner bearing elements. The spaced annular series of balls 70 and 71 effectively support the inner portions of the cutters 13 for free rotation.

The thrust washers 66 are shaped to have extensive cooperation with the faces 22 on the legs 20 and to fit in the concave ends of the cutters 13 with suitable clearance. The washers 66 have reduced cylindrical portions extending into the enlarged outer portions of the cutter openings 51 and ball races or grooves 72 are provided in these reduced washer portions and the end parts of the adjacent race members 65 to oppose the grooves 62. The grooves 72 have their larger portions in the washers 66. Annular series of balls 73 are arranged in the opposite grooves 62 and 72. The grooves 62 and 72 are of substantial depth and the balls 73 are operable to transmit the radial thrusts and the end thrusts in both directions between the cutters 13 and the inner bearing parts. To facilitate the assembly of the balls 70 and 71 in the set of closely fitting grooves 60, 67, and 61 and 68, notches 74 are provided in the ends of the members 64 and 65 to commun-
of the inner grooves 86 of the cutter 14 and the race member 77 is then arranged in the opening 85 to engage against the balls 86. The balls 86 are then introduced one at a time into the groove 81 and the portion of the inner groove 80 of the cutter 14 and the race member 77 is then arranged in the opening 85 to engage against the balls 86. The projecting outer portion of the dowel pin 91 is received in the socket 90 of the race member 78 when the member is arranged in place. The assembly of the cutter 14 and its bearing elements is introduced between a leg 20 and the web 23 and is moved inwardly until the socket 79 of the race member 77 fully receives the boss 24 of the web 23. The cutter 13 is then assembled with its bearing elements. The series of balls 73 is arranged in the outer groove 82 of the cutter 13 and the thrust washer 86 is then arranged in the enlarged outer portion of the opening 51 to engage against the balls 73. The race member 65 is then arranged in the opening 51 to engage against the balls 73. The balls 71 are introduced one at a time into the groove 81 and the portion of the groove 80 in the race member 65 through the notch 74 in the member 65. The race member 64 is then arranged in the opening 51 to engage against the balls 71. The balls 70 are introduced one at a time through the notch 74 in the race member 64 into the groove 60 and the portion of the groove 61 in the race member 64. The dowel pin 91 may be carried in the openings 88 of the race members 64 and 65 to have one end introduced into the socket 89 of the thrust washer 66. Following the introduction of the balls 70 into the groove 60 the inner race member 63 is positioned in the opening 51 to engage against the balls 70. The projecting inner end of the dowel pin 91 is received in the socket 89 of the race member 63 when the race member is arranged in place. The assembly of the cutter 13 and its bearing elements is then introduced between the leg 20 and the cutter 14 which has been positioned on the web 13 as described above. In a similar manner the second set of cutters 13 and 14 are arranged on the body 10. When the sets of cutters 13 and 14 have been arranged between the legs 20 and the web 23 and in axial alignment with the opening 57 in the web 23 and the openings 56 and 55 in the legs 20, the pin 55 is passed through the opening 56, the bearing elements of the cutters 13 and 14 and the bearing element in the web 23 to have its end portion threaded into the opening 55. The lugs 75 may then be welded to the legs 20.

The means 16 for flushing the cutters 11 and 13 and 14 includes ports or openings 92 in the walls of the body 10 communicating with the lower end of the portions in facing downwardly and outwardly between the legs 18 and the web 23 toward the cutters 11. Tubular bushings 83 are inserted in the openings 92 and are welded to the body 10 at 94. The longitudinal openings 95 in the bushings 83 are tapered having downwardly or upwardly convergent walls. Beans or nozzles 86 are removably arranged in the openings 95 of the bushings 83. The nozzles 86 have their exteriors tapered to correspond to the taper of the openings 95. The nozzles 86 are inserted downwardly in the openings 95 to seat therein. Fluid discharging openings 97 extend through the...
nozzles 95. The openings 97 may be downwardly convergent to produce a jetting action. The streams of fluid under pressure discharged from the nozzle openings 97 impinge against the cutters 11 to wash their teeth 29. It will be observed that the fluid under pressure passing through the nozzles 95 tends to tighten or at least hold the nozzles in the tapered openings 95. The fluid handling means 16 further includes or provides openings 98 in the body 10 communicating with the lower end of the passage 18 and opening downwardly toward the passage opening 13 and 14. The openings 98 may be tapered or of downwardly increasing diameter. Wear preventing bushings 99 are provided in the openings 98. The bushings 99 are adapted to discharge streams of circulation fluid downwardly against the cutters 13 and 14 to flush their teeth 52 and 54. Welds 100 may secure the bushings 99 to the body 10.

In operation the bit body 10 is secured to the lower end of the drilling string and is rotated in the well in the usual manner. The outer cutters 14 act on the outer portion of the bore to cut the bore to size and are supported by the series of balls 42 and 44 for free rotation about downwardly and inwardly inclined axes. The sets or pairs of opposing grooves 39 and 41, and 49 and 43 are of substantial depth and have extensive engagement with their walls so that the forces or pressures are well distributed and are materially reduced in intensity. This promotes the long life of the bearings. The balls 42 and 44 cooperating with their respective grooves are operable to transmit end thrusts in both directions as well as the radial thrusts and thus constitute the sole means for rotatably supporting the cutters 11 on the inner bearing parts.

The inner cutters 13 and 14 are independently rotatable about a common transverse axis to act on the formation at the bottom of the well bore. The cutters 13 are rotatably supported by the annular series of balls 70, 71 and 73. Each of these series of balls is operable to transmit the end thrusts in both directions and by the radial thrusts. The grooves receiving the balls 70, 71 and 73 are of such depth that the balls have extensive engagement with their walls so that the forces are well distributed and the pressures are of less intensity. In a like manner the inner and the balls 42 and 44 have extensive engagement with their walls so that the forces are well distributed and the pressures are of less intensity. The inner cutters 13 and 14 are adapted to discharge streams of circulation fluid downwardly against the cutters 13 and 14 to flush their teeth 52 and 54. Welds 100 may secure the bushings 99 to the body 10.

2. A well bit comprising a body, two substantially diametrically opposite legs projecting from the body, a web projecting from the body and spaced between the legs, the legs and web having aligned openings, a single support member extending between the legs with an end portion threading in an opening in one leg and its intermediate portion supported in the opening in the web, the other end portion of the member extending through the opening in the other leg, a head on the said other end of the member bearing inwardly against said outer end of roller cutters rotatably supported on the member between the legs and web.

3. A well bit comprising a body, two substantially diametrically opposite legs projecting from the body, a web projecting from the body and spaced between the legs, the legs and web having aligned openings, a single support member extending between the legs with one end portion threading in an opening in one leg and its intermediate portion supported in the opening in the web, the other end portion of the member extending through the opening in the other leg, a head on the said other end of the member bearing inwardly against said roller cutters rotatably supported on the member between the legs and web.

4. In a rotary well drilling bit, spaced supports, a pin extending between and carried by the supports, a roller cutter having an opening and surrounding the pin, thrust washers on the pin received in the cutter opening and projecting from the ends of the cutter to bear against the supports, a race member on the pin between the washers and having its ends in abutment with the ends of the washers to space them apart, there being spaced annular grooves in the wall of the opening, there being grooves in the peripheries of the washers and the race member at their abutting ends opposing the races of the openings, and series of balls in the said opposing grooves rotatably supporting the cutter.

5. In a rotary well drilling bit, spaced supports, a pin extending between and carried by the supports, a roller cutter having an opening and surrounding the pin, thrust washers on the pin received in the cutter opening and projecting from the ends of the cutter to bear against the supports, a race member on the pin between the washers and having its ends in abutment with the ends of the washers, there being spaced annular grooves in the wall of the opening, the washers and race member having aligned axial openings, a pin in the said aligned opening holding the washers and race member against relative rotation, means securing a washer to a support to hold the washer against rotation of the pin, there being grooves in the peripheries of the washers and the race member at their abutting ends opposing the races of the opening, and series of balls in the said opposing grooves rotatably supporting the cutter.

6. A well bit comprising, a body having spaced legs and a web spaced between the legs, the legs and web having aligned openings, a pin extending through the openings and supported by the legs and web, bosses on the opposite sides of the web, sets of cutters surrounding the pin between the legs and web, bearings on the cutters received in the openings on the pin with their ends in abutment, the cutters having internal grooves, the abutting end portions of said members being concave to present annular grooves opposing the grooves in
the cutters, and balls in the opposing first and second mentioned grooves rotatably supporting the cutters, the innermost members having sockets receiving the bosses.

7. A well bit comprising, a body having spaced legs and a web spaced between the legs, the legs and web having aligned openings, a pin extending through the openings and supported by the legs and web, bosses on the opposite sides of the web, sets of cutters surrounding the pin between the legs and web, bearing members arranged on the pin with their ends in abutment, the cutters having internal grooves, the abutting end portions of said members being concave to present annular grooves opposing the grooves in the cutters, balls in the opposing first and second mentioned grooves rotatably supporting the cutters, the innermost members having sockets receiving the bosses, means connecting the outermost members with the legs to hold them against rotation, and means connecting the other members including said innermost members with the outermost members to hold them against rotation.

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