March 8, 1960 J. B. COULTER, JR 2,927,778

ROTARY DRILL CUTTERS

Filed July 5, 1956

3 Sheets-Sheet 1

Fig. 1.

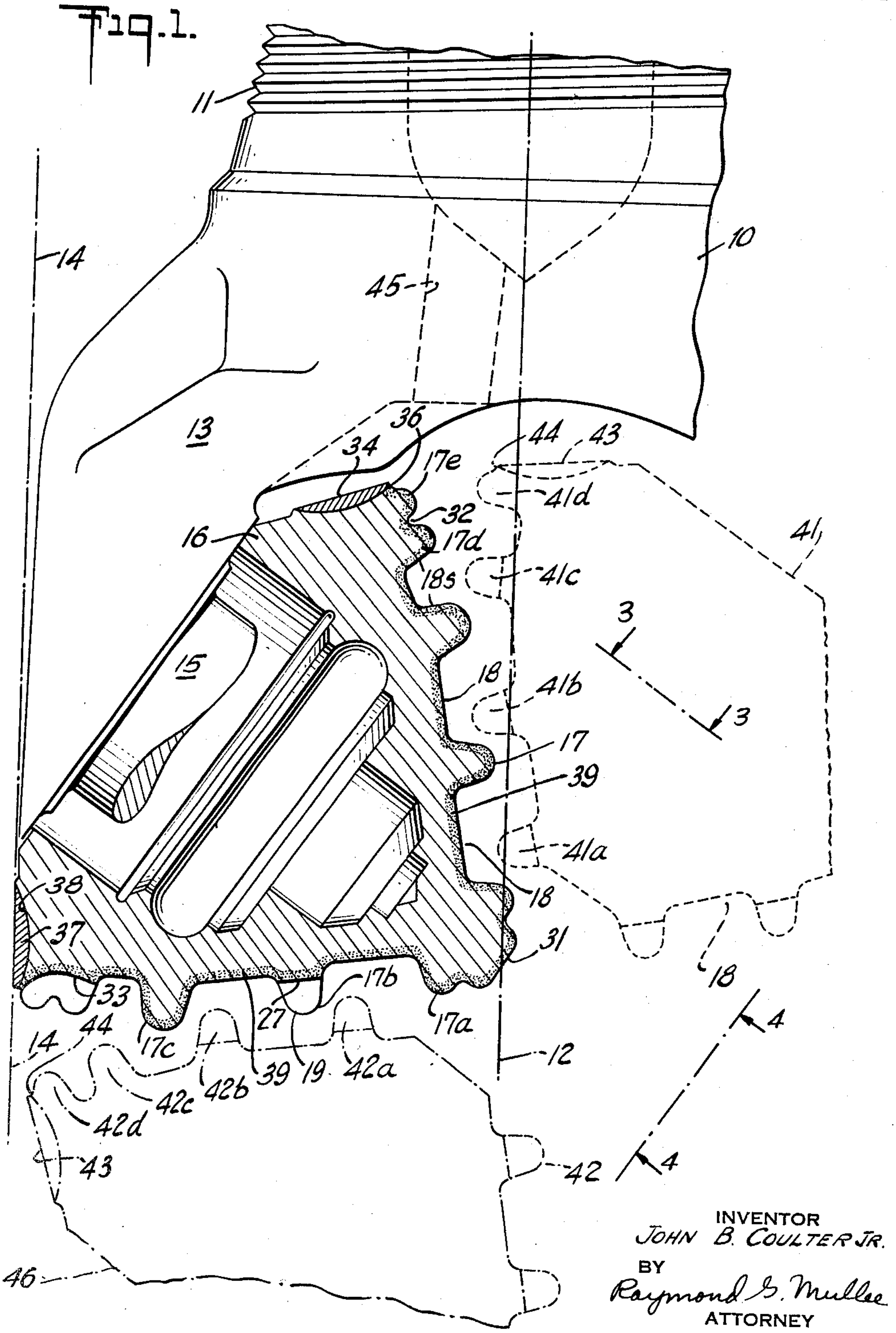

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Fig. 2.

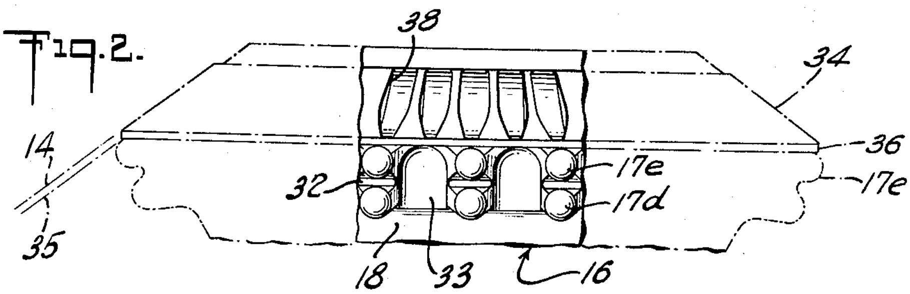

Fig. 3.

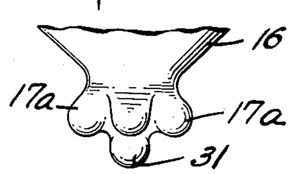

Fig. 4.

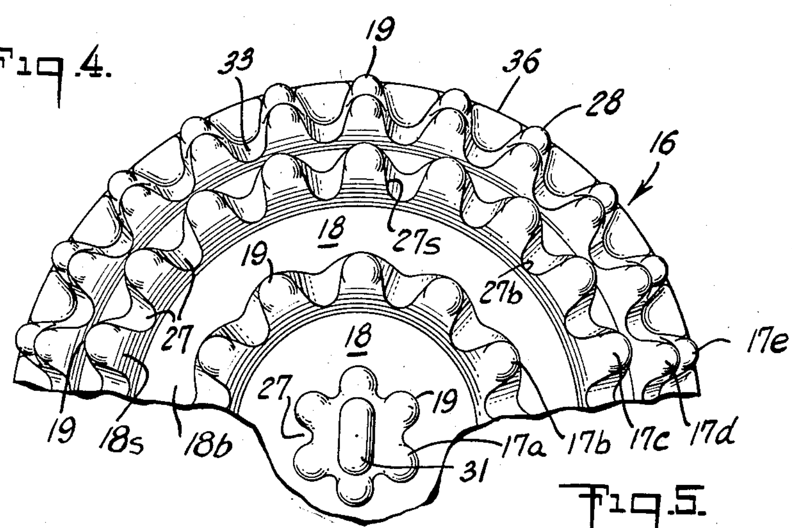

Fig. 5.

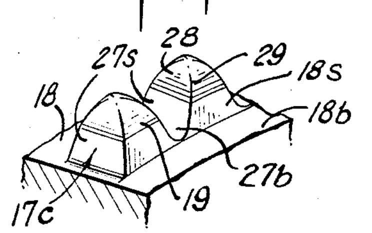

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Fig. 6.

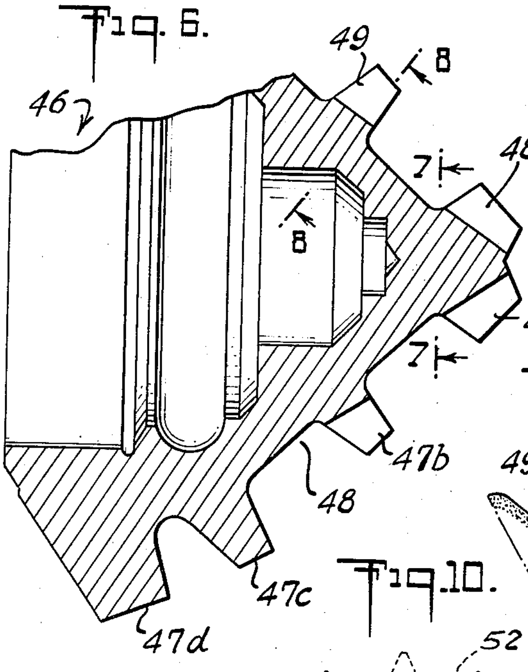


Fig. 7.

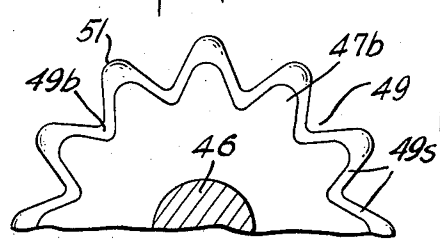


Fig. 8.

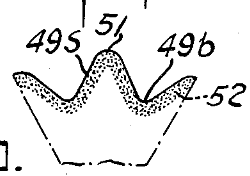


Fig. 9.

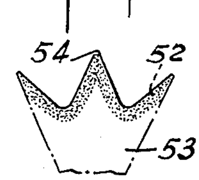
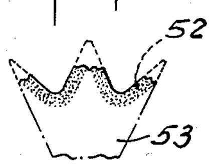


Fig. 10.



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ROTARY DRILL CUTTERS

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Application July 5, 1956, Serial No. 595,982

11 Claims. (Cl. 255—349)

This invention relates to rock bits for deep well drilling and particularly to the tooth formation on the rotary cutters. It has especial, though not exclusive, application to cutters of the cone type which operate on the earth formation with an approximately true rolling action.

The usual cone type rock bit comprises three conical cutters each having widely spaced circumferential rows of teeth offset in relation to the corresponding rows on the other cutter to drill the formation at the bottom of the hole, the particles of detritus thus dislodged being removed by the action of a liquid flushing fluid or of pressurized air or gas. Cone bits in common use fall into two general classes, those having sharp chisel teeth and those in which the teeth are made of hardened inserts or plugs with an ovoid portion projecting beyond the cone surface. The chisel tooth operates with a chipping or slicing action and will drill in all but the very hardest formations. It is characterized by a sharp cutting edge or crest which extends radially of the cone from one circumferential groove to the next, the flanks of the teeth being separated from adjacent teeth in the same circumferential row by means of deep radial grooves, which act to receive the loosened earth formation and permit deep penetration of the teeth. In extremely hard and abrasive formations such as quartzite, granite and flint, the chisel toothed cone will not drill effectively and is replaced by the inserted plug type of cutter which is so designed that the blunt areas of the tungsten carbide plugs engage the formation with a crushing action and thus fracture the formation rather than chisel it.

The inserted plug type of cutter has the disadvantage in that the cost is about five times that of a conventional chisel toothed cutter. A further disadvantage of the inserted plug type is that it loses much of its effectiveness when it reaches the end of an extremely hard formation for which it was designed and encounters softer formation. This is due to the fact that the projecting portions of the tungsten carbide plugs are necessarily very short and do not have the penetrating action required for softer formations. Still another disadvantage is that the plugs sometimes are dislodged from their sockets.

An object of this invention is a provision of a cutter having a novel form of tooth capable of drilling in extremely hard formation, but which can be manufactured at a fraction of the cost of the inserted plug cutter now used for the same purpose.

Another object is the provision of a rock bit adapted for drilling in both extremely hard and in relatively softer formations, without requiring the bit to be pulled and changed as the drill encounters a different stratum.

A further object is to increase the compressive strength of a cutter tooth thereby making it possible to case harden the cutter to a greater depth without the accompanying danger of chipping off the tooth crests.

A feature of this invention is a tooth formed integral with the cutter body, having a rounded or cylindrical crest capable of drilling with a crushing action and also having a root portion lying below the crest which provides deep penetration.

In the accompanying drawings:

Fig. 1 is a fragmentary view of a rock bit showing in longitudinal section a conical cutter embodying this invention, and also showing in broken lines the interfitting positions of the remaining two cutters;

Fig. 2 is a fragmentary plan view of the heel portion of the cutter, looking at right angles to the axis of rotation thereof;

Fig. 3 is a fragmentary plan view of the tip or apex portion of the cutter, when viewed from the line 3—3 in Fig. 1 in the direction of the arrows;

Fig. 4 is an end view of the illustrative cutter with the lower part broken away, looking along the axis of the cutter from the line 4—4 in Fig. 1 in the direction of the arrows;

Fig. 5 is a fragmentary view in perspective of two adjacent teeth on said cutter;

Fig. 6 is a longitudinal section, partly broken away, of a modified form of cutter;

Fig. 7 is a half cross section along the line 7—7 in Fig. 6, showing a half row of the modified teeth in elevation;

Fig. 8 is a fragmentary section of one of the modified teeth along the line 8—8 in Fig. 6, showing the carburized case on the tooth;

Fig. 9 is a view similar to Fig. 8 showing a tooth having the exterior surface of a conventional chisel tooth but a carburized case comparable in depth to the case of the tooth in Fig. 8; and

Fig. 10 is a view of the tooth of Fig. 11 showing the cutting edge chipped off.

Referring to Fig. 1, a bit head **10** of the usual form is provided with a threaded shank **11** for attachment to the lower end of a drill stem (not shown), whereby the bit head may be rotated about the vertical axis **12** of the bore hole. The bit head has three legs **13** (one shown) extending downwardly and outwardly toward the side wall **14** of the bore hole. Each leg supports, near its lower end, a spindle **15** which extends downwardly and inwardly. Each spindle **15** has an axis of rotation which lies in the same vertical plane as the axis of revolution **12** of the drill bit and is spaced 120° apart from the vertical plane of the axis of each remaining spindle. The spindle **15** provides a support for a conical cutter **16**. Suitable rolling and friction bearings (not shown) are interposed between the cutter and the spindle according to the usual well-known arrangement.

The surface of the conical cutter **16** comprises a series of circumferentially extending rows of teeth **17***a*, **17***b*, **17***c* and **17***d* of novel formation, separated by wide and deep circumferential grooves **18**; also a row of similar teeth **17***e* in radial alinement with teeth **17***d*. Each circumferential groove has a conical bottom **18***b* Figs. 4 and 5 and two straight sides **18***s* diverging from the bottom. Connecting the straight sides **18***s* of two adjacent grooves is a rounded surface **19** which forms the crest portion of the teeth **17***b* and **17***c*. In a longitudinal section as shown in Fig. 1, each tooth **17***b* or **17***c* comprises a root portion bounded between the tapering straight sides **18***s* and a tip or crest portion forming a half circle **19** connecting the sides. The root portion which lies below the center of the arc **19** has a substantial depth, being approximately equal to or even greater than the crest portion. This is an important feature of the invention as will be explained later.

The teeth are preferably formed on the face of the cutter by a machining operation which includes the removal of metal from the body of cutter **16** to form the circumferential grooves **18**. The continuous circumferential ridges which lie between and adjacent to the circumferential grooves **18** are then broken up into rows of individual teeth. This is accomplished by cutting transverse or radial grooves **27** in each row to correspond to the number of teeth; for example, six teeth in row **17***a*, twelve teeth in row **17***b*, twenty teeth in row **17***c* and twenty-four teeth in each of rows **17***d* and **17***e*. Referring to Figs. 4 and 5, each radial groove comprises a curved bottom portion **27***b* and two straight sides **27***s* diverging from the bottom. A rounded surface **28** connects the straight sides of two adjacent radial grooves and forms part of the crest portion of the tooth **17**. The sides **27***s* of the radial grooves **27**, which form the flanks of the teeth **17** are similar to the sides **18***s* of the circumferential grooves, but the radial grooves are not as deep or as wide as the circumferential grooves **18**. The center of curvature of the rounded bottom **27***b* lies below (closer to the cutter axis than) the centers of curvature of rounded surfaces **19** and **28**.

Referring to Fig. 5, the individual tooth **17***c* comprises a root portion of pyramidal shape having two tapered side walls **18***s* lying between circumferential grooves **18**, and having two end walls or flanks **27***s* lying between radial grooves **27**. Above the root portion, the tooth has a crest portion, the exposed area of which is defined by the intersection of two approximately cylindrical surfaces **19** and **28**. These two cylindrical surfaces intersect along approximately radial lines **29**. If desired, the lines **29** may be smoothed out by filling or grinding so as to present substantially a continuous convex surface, of approximately hemi-spherical shape, on the crest portion of the tooth.

The teeth **17***b* are substantially of the same shape as the teeth **17***c* except for a slight difference in size and proportions. The teeth **17***a* are similar as to the rounded tip portions but are not provided with the pyramidal root portion due to space limitations. As seen in Figs. 1, 3 and 4, the tip portion of the cone cutter immediately in front of row **17***a* is provided with a dull blade **31** extending diametrically at the apex end of the cone. The blade is positioned to cut the center of the bore hole and thus perform the same function as the usual spear point but is so shaped as to avoid any sharp corners. Referring to Figs. 2 and 4, the teeth **17***d* and **17***e* are in line with each other and form practically a single row of teeth as they are separated by a relatively narrow circumferential groove **32**. Radial grooves **33** extend between the teeth **17***d* and part way through the outermost row **17***e*. Grooves **33** are similar to the radial grooves **27** but lose depth as they approach the heel of the cone cutter **16**. The teeth **17***e* are spaced from the heel **34** of the cone cutter leaving a marginal area between the side wall of the bore hole and the area cut by the outermost row of teeth **17***e*. This area, which is represented by the space between the broken lines **14** and **35** in Fig. 2, is cut by an offset shoulder **36** at the heel of the cone. The shoulder also constitutes an annular wall which terminates or closes the outer end of the radial grooves **33**. The heel surface **34** rubs against the side wall **14** of the bore hole and maintains the gage of the hole, regardless of wear on the outermost row of teeth **17***e*. To resist wear the heel **35** is covered with hard facing material **37** such as tungsten carbide. To facilitate the application of such material, the heel may be provided with radially extending recesses **38** (Fig. 2).

As shown in Fig. 1, the peripheral surface of the cone cutter **16** is carburized and heat treated to provide a case hardened skin **39**. In accordance with this invention, such carburizing is carried to a further degree and to a further depth of case as compared with standard practice. With the usual form of cutter, having chisel shaped teeth, any attempt to increase the percentage or depth of carburization would cause excessive brittleness with the result of the teeth being chipped and broken off along the sharp cutting edges. This, of course, would impair the cutting properties of the drill bit and shorten its life. With the present invention, however, it is feasible to increase the

degree and depth of case hardening beyond the normal safe limit and without any corresponding increase in the danger of chipping. This is made possible by the fact that the invention has eliminated sharp corners and instead substituted a form of tooth whose surface merges with other teeth in the same row to present an undulating formation of generally knuckle shape. The relatively deep hard case **39** increases the hardness, wear resistance, and life of the cutters considerably. This result is necessarily accompanied by a reduction in the toughness of the case but such reduction may be tolerated without ill effects because the teeth of this invention are so shaped that they absorb impact loads without fracturing.

Referring to Fig. 1, the cutter or cone **16**, which has been described in detail, cooperates with two complementary cutters **41** and **42**. Cutter **41** has circumferential rows of teeth **41***a*, **41***b* and **41***c*, arranged to cut an annular formation on the bottom of the hole closely surrounding the annular areas cut by the teeth **17***a*, **17***b* and **17***c* respectively. The teeth **41***a*, **41***b* and **41***c* are similar in shape to the teeth **17***b* and **17***c*. Teeth **41***a*, **41***b* and **41***c* extend into the circumferential grooves **18** separating the rows of teeth **17** on cutter **16**. Near its heel, cutter **41** is provided with an outer row of teeth **41***d* arranged to track over the area cut by the row **17***e*, and also with a hard surfaced heel **43** arranged to cooperate with an annular offset shoulder **44** to cut the formation at the outer edge of the hole. Cutter **42** is provided with a similar hard surfaced heel **43**, offset shoulder **44** and outer row of teeth **42***d*. Cutter **42** also has circumferential rows of teeth **42***a*, **42***b* and **42***c*, similar to the teeth **41***a*, **41***b* and **41***c*, and cutting an area immediately surrounding the annular area cut by the latter. Teeth **42***a* and **42***b* interfit within the grooves between the rows of teeth on both of the other two cutters, thus providing a self cleaning action.

In operation, the bit head **10** is revolved about its vertical axis **12** carrying with it the cutters **16**, **41** and **42** which roll over the bottom of the bore hole, each about its individual axis with an approximate true rolling motion. Due to the wide grooves **18** and the staggering of the teeth in one circumferential row (**17***c*) out of radial alignment with the teeth in other rows (**17***a*, *b*, *d*) there are only a few teeth in contact with the bottom of the hole at any one time. Assume that the earth formation is extremely hard and abrasive so that it could not be cut by the conventional chisel tooth. The drill is turned at a relatively slow rate, say thirty revolutions per minute under tremendous pressure which may run as high as 100,000 pounds in a bit of the 8¾" size. This weight is concentrated upon a few minute areas at the bottom of the bore hole represented by the points of tangency with the curved crests **19**, **28** of teeth **17** (*a*, *b*, *c*, *d*) and the corresponding crests on the other two cutters. The effect is to fracture the hard rock at the bottom of the bore hole with a crushing action, thus dislodging small particles of detritus which are carried to the surface of the hole by the action of the flushing fluid discharged through suitable ports **45** in the bit head. The crushing pressure on the rock has its counterpart in a reactive force which tends to crush the teeth **17***a*, *b*, *c*, *d*, *e* but such pressure is resisted by the arch-like construction of the teeth, which gives them great compressive strength. At the same time, abrasion on the teeth is resisted by the relatively deep hardened case **39** thus prolonging the life of the cutters.

As will be apparent from Fig. 1, the circumferential rows of knuckle shaped teeth **17***a*, *b*, *c*, *d* on cutter **16**, **41***a*, *b*, *c* on cutter **41** and **42***a*, *b*, *c* on cutter **42** are offset and spaced radially of the bore hole so that each cuts a separate annular area at the bottom of the hole, such areas being discrete and separated by annular spaces which are not in direct contact with the cutters. Such annular spaces, however, are broken away due to the fact that the action of the teeth on the rock formation has a crushing effect with the fracturing force being transmitted laterally as well as downward on the rock. The space surrounded by the inner-most row of teeth 17a is cut by the dull blade 31.

The heel rows of teeth 17e, 41d and 42d roll over a common annular area near the side wall 14 of the bore hole. These teeth, however, are spaced from the wall 14 by about 1/16" leaving a thin marginal area which provides an open space to receive cuttings. This area is cut by the offset shoulders 36 and 44, each of which acts as a reamer to shave the side of the hole. Since the teeth in the heel rows 17e, 41d and 42d do not at any time directly engage the side wall 14, the wearing of the teeth in use will not affect the gage of the hole which is maintained by the tungsten carbide or hard facing 37 applied to the heel 34 of the cone.

Assume now that the rock bit when only partly worn reaches the end of the layer of extremely hard and abrasive formation and strikes a relatively softer formation such as a stringer of shale. Unlike the prior art hard formation bit of the inserted plug type, the rock bit of this invention need not be pulled and replaced by a chisel toothed bit. Instead it is permitted to continue to run, preferably at a higher speed but lower pressure. The cutter teeth of this invention, notwithstanding their blunt tips 19, 23, will continue to drill without "balling up" because the root portion 18s provides sufficient length of tooth to permit them to penetrate deeply into the relatively soft earth formation. As shown in Fig. 1, the rows of teeth on one cutter project into the grooves 18 separating the teeth on another cutter and thus provide a self cleaning action to remove any formation adhering to the cutters.

From the foregoing description, it will be seen that the present invention will drill effectively in relatively soft and medium formations heretofore considered suitable for drilling only by chisel teeth but not by teeth of the inserted plug type; and also in extremely hard formations heretofore considered as suitable for drilling only by bits having short inserted plugs and not by chisel toothed bits. In short, the invention obviates the necessity of changing from one type of bit to the other and back again. The invention is particularly applicable to extremely hard limestones where shale stringers are interspersed between the hard rock strata. In cases such as this, the inserted carbide bit must be pulled out of the hole and a conventional chisel tooth bit run back in, and vice versa, with each bit, making only a few feet of hole. Where these formations are encountered the well is usually more than ten thousand feet deep and the time involved in changing a bit, or "making a round trip" is very considerable and adds greatly to the cost of drilling operations.

Even in uniform hard rock formations where there is no necessity for changing the bit before it is worn out, the invention has the advantage of economy in the cost of manufacture as its cost is only a fraction of that of the inserted carbide type of bit, although its performance compares favorably. Another advantage is that the teeth being an integral part of the cone cutter cannot fall out as happens with teeth of the inserted plug type.

Figs. 6, 7 and 8 disclose a modification of this invention which possesses some of the characteristics of the chisel tooth while retaining some of the advantages of the rounded crest. Fig. 6, which is a longitudinal section, is similar to a sectional view of a conventional chisel toothed cone. The cutter 46 shown therein is provided with circumferential rows of teeth 47(a, b, c, d) separated by circumferential grooves 48; the teeth in each row being divided up by transverse or radial grooves 49. The sides of the circumferential grooves and, therefore, the sides of the teeth, extend along a straight line running from a point close to the bottom of the groove to a point at the crest of the tooth. The radial grooves 49 comprise a curved bottom portion 49b and two straight side portions 49s. Connecting the sides 49s is a cylindrical surface 51 which constitutes the crest of the tooth 47. The

crest 51 is generally in the shape of a cylinder, the axis of which is spaced further away from the axis of the cutter 46 than is the center of the arc 49b, thus providing a tooth with a root portion and a novel crest portion lying above the root. It will be understood that the cutter of Fig. 6 is arranged in association with two complementary cutters, each having a heel row which tracks the heel row 47d and also having inner rows in offset interfitting relation to the rows 47a, b and c. The cutter shape of Figs. 6, 7 and 8 is useful in formations somewhat softer than those for which the Fig. 1 cutter was designed, where it is desired to have more area at the bottom of the hole in contact with the cutting teeth. The modified cutter of Fig. 6 is capable of drilling with a combined crushing and chipping action and has a longer life than the conventional chisel tooth. This is made possible by the cylindrical shape of the crest of the tooth which permits application of case hardening to a skin 52 (Fig. 8) having a depth greater than the normally safe limit for chisel teeth.

Fig. 9 shows a chisel tooth 53 which has a conventional shape including a sharp cutting edge 54. The illustration in Fig. 13, however, differs from standard practice in that it shows a depth of case 52 comparable to that of the present invention. It will be seen that the shape of tooth is not suitable for a deep case because of the sharp edges. The result would be a chipping or breaking off of the sharp edge as shown in Fig. 10. For that reason, a deep case is generally avoided which prevents utilization of the cutters for a long life. The hard and deep case, with the resulting increase in hardness, wear resistance and cutter life is made possible by the present invention, due to the cylindrical crest 51 which merges with the radial grooves 49 to provide a smooth undulating surface resembling a knuckle gear, free from sharp edges.

What is claimed is:

1. In an earth boring drill, a roller cutter of approximately conical shape, having a body adapted to be mounted for rotation on its axis, a plurality of rows of teeth integral with said body, said rows being separated by circumferential and radial grooves, each tooth having a root portion and a convex tip portion, the tip portion being semi-circular in section, the root portion having an altitude approximately equal to the altitude and the radius of curvature of the tip portion and being generally of the shape of the frustum of a pyramid, said root portion having two opposite sides adjacent the circumferential grooves and having two opposite flanks abutting the radial grooves, each side and each flank of the root portion being tangent to the adjacent surface of the tip portion, the tip portion being operable on the bottom of the earth formation with a crushing action and the root portion being effective to provide deep penetration.

2. In a rotary well drill, a conical cutter having its cutting surface converging toward the central axis of the drill and mounted to contact the bottom of the hole with an approximately true rolling action, said cutter having a body and a plurality of teeth each of which projects integrally from the body and at an angle inclined toward the apex of the cutter so as to extend vertically downward when in contact with the bottom of the hole, said teeth being arranged in rows extending around the circumference of the cutter, one of said rows including a plurality of teeth each having a convex tip portion mounted upon a root portion lying below the tip portion, the opposite sides of said one row of teeth being bounded by circumferential grooves and the flanks of the individual teeth in said one row being separated by radial grooves extending below the tip portions and into the root portions, thus providing deep penetration of the tip portions into the earth formation, the surface of said convex tip portion having the shape of a semi-circle in a section taken transverse to the radial grooves, said

semi-circle being tangent at its ends with the flanks of the root portions, the radius of the semi-circle being approximately equal to the altitude of the tip portion, whereby the tip portion is operable on the bottom of the earth formation with a crushing action, the altitude of the root portion being approximately equal to the altitude of the tip portion.

3. In a rotary well drill having cutters with their cutting areas converging toward the central axis of the drill and mounted to contact the bottom of the hole with an approximately true rolling motion, cutting teeth formed on said cutters in circumferential rows separated by circumferential grooves, each of said teeth having a pyramidal root portion and a rounded tip portion, the rows of teeth on each cutter being offset relative to the teeth on adjacent cutters and adapted to interfit therewith, the opposite sides of each row of teeth being deeply cut and spaced apart to allow clearance between adjacent interfitting teeth, the tip portion of each of said teeth in one of the rows extending into the associated groove between the rows of teeth on each of the adjacent cutters, the tip portion being rounded on opposite sides, the surface of the tip portion forming in longitudinal section an arc extending from one circumferential groove to the next, said arc having a diameter approximately equal to the distance separating two adjacent circumferential groovs and being tangent to the sides of the root portions of the teeth, thus presenting a blunt crest to engage the earth formation with a crushing action, the root portions of the teeth in each row being separated by radial grooves extending for a substantial depth below the tip portions adapted to provide deep penetration of the teeth into the earth formation.

4. A rotary well drill according to claim 3, in which the rows of teeth and body of the cone form an integral structure, the surface of the cutter including the teeth and grooved portions being case hardened to a substantial depth.

5. A rotary well drill according to claim 3, in which the flanks of the teeth which lie adjacent the radial grooves are connected by a crest surface which forms an arc in a section taken through the plane of the row of teeth, whereby the tip portion of each tooth is of approximately hemispherical shape.

6. In an earth boring drill, a roller cutter according to claim 3, in which the tip portion is formed by the intersection of two half cylinders having axes at right angles to each other.

7. In an earth boring drill, a roller cutter of approximately conical shape having a body adapted to be mounted for rotation on its axis, the apex portion of the cutter lying adjacent the axis of rotation of the drill, a plurality of teeth on said body including a circumferential row of teeth on the apex portion, said last named teeth being of substantially hemispherical shape to engage the earth formation with a crushing action, and a blade formed at the apex end of the cutter, said blade extending diametrically of the circumferential row aforesaid and being in the shape of a half cylinder terminating at each end in a quarter sphere to form a smooth, dull surface, said blade extending to and beyond the axis of rotation of the drill to engage the earth formation simultaneously on both sides of the center of the hole.

8. In an earth boring drill, a roller cutter of approximately conical shape, having a body mounted for rotation on its axis, a plurality of widely spaced rows of teeth integral with said body, circumferential grooves separating said rows, each tooth having a root portion and a convex tip portion, the tip portion of each tooth having an arcuate shape in a section taken through the plane of the row of teeth and also having an arcuate shape in the plane of the axis of rotation of the cutter, whereby the tip portions operate on the bottom of the earth formation to fracture the latter with a crushing action in extremely hard formations, each root portion having approximately parallel sides extending between the convex tip portion and the body of the cutter and being tangent to the arcuate surface of the tip portion, the root portions in each row of teeth being separated by radial grooves adapted to receive the earth formation in the spaces between the teeth whereby the root portions may penetrate deeply into relatively softer formations.

9. A roller cutter according to claim 8, characterized in that the root portion of the tooth has substantially the same altitude as the convex tip portion thereof.

10. In an earth boring drill, a roller cutter according to claim 8, the flanks of said root portions having approximately the shape of a trapezoid, one side of said trapezoid being defined by the inner edge of associated radial groove, another side being defined by a straight line which is shorter than and parallel to the side first mentioned, the tip portions of each tooth having segmental curved areas which are tangent to said flanks and which join the latter along the entire length of the shorter line aforesaid, thus providing a substantially smooth surface covering the tip portion and the flanks.

11. A roller cutter of approximately conical shape, having a body mounted for rotation on its axis, a plurality of circumferential rows of teeth extending integrally from said body, circumferential grooves separating said rows, each tooth having a root portion, the root portions in each row of teeth being separated by radial grooves adapted to receive the earth formation in the spaces between the root portions, one or more of said teeth having a convex tip portion arranged to engage the earth formation with a crushing action, characterized in that the surface of the convex tip portion comprises a pair of sectors forming portions of a toroidal surface extending circumferentially and a second pair of sectors forming portions of a cylindrical surface extending radially, the sectors in the first pair alternating with the sectors in the second pair, the adjacent sectors meeting each other along four radial lines.

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