ABSTRACT

A drill bit comprising a cutter assembly, further comprising a planar table and a cutter substrate coupled to the planar table, wherein the cutter substrate has a cutter body axis and wherein the planar table is operable to rotate about the cutter body axis. The planar table may be exposed to the rock formation for cutting purposes but may rotate to reduce the time that any specific portion of the cutting edge is exposed to the formation to extend the life of the planar table, among other benefits.
CIRCUMVOLVE CUTTERS FOR DRILL BIT

FIELD OF THE INVENTION

[0001] The present invention relates generally to drilling tools and more particularly to drill bits.

BACKGROUND

[0002] Cutters are often utilized in drill bits for shearing through rock formations. Oftentimes, these cutters become dull and require replacement, which limits the rate of penetration into the rock as well as footage drilled. The cutters may be damaged by impact, thermal degradation and abrasive wear, factors which significantly reduces the life of the cutting elements. For example, while polycrystalline diamond compact (PDC) bits are effective when drilling in soft formations, the PDC bits' performance has been limited while drilling in hard-rock and abrasive formations due to impact damage and wear.

[0003] The current trend in the industry is to force, vector, dynamic and energy balance PDC drill bits for stability purposes. However, these methods do not take into consideration the instability of the drill string. The drill string can have a dramatic effect on bit performance with respect to impact damage to cutters.

[0004] Therefore, there is a need to provide an apparatus and method for drilling using a drill bit operable to compensate for abnormal loading resulting from vibration and whirl associated with bit and/or drill string instability. There is also a need to provide drilling at an improved rate of penetration. There is a further need to prolong the cutter's life and the drill bit's life by reducing the rate of damage caused by thermal degradation and abrasive wear.

BRIEF SUMMARY OF THE INVENTION

[0005] In view of the foregoing and other considerations, the present invention relates to methods and apparatus for improving drill bit performance and operational life by reducing the rate of damage caused by impact, thermal degradation and abrasive wear.

[0006] Accordingly, a cutter assembly for a drill bit is provided. The cutting assembly comprises a cutting head, and a cutter substrate coupled to the cutting head, wherein the cutter substrate has a cutting head axis and wherein the cutting head is operable to rotate about the cutter body axis. In another embodiment, the cutting assembly comprises a planar table, and a dampering mechanism operable to reduce an impact force applied to the drill bit in response to contact between the planar table and a solid surface as the drill bit engages the solid surface.

[0007] A method for drilling a formation is provided. The method includes the steps of providing a drill bit comprising a cutter assembly, wherein the cutter assembly comprises a cutter substrate having a planar table operable to rotate axially about a cutter body axis and comprising a cutting surface, disposing the drill bit in a well bore adjacent to a formation, rotating the drill bit around a bit axis, engaging a portion of the planar table to the formation to cut a portion of the formation, and dampening at least a portion of the impact on the drill bit as the drill bit engages the formation.

[0009] The foregoing has outlined the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing and other features and aspects of the present invention will be best understood with reference to the following description of a specific embodiment of the invention, when read in conjunction with the accompanying drawings, wherein:

[0011] FIG. 1 shows a side view of an embodiment of the drill bit of the present invention;

[0012] FIG. 2 depicts a cross-sectional view of a cutter assembly coupled to the drill bit in accordance with one embodiment of the present invention;

[0013] FIG. 3 illustrates a cross-sectional view of the cutter assembly coupled to the drill bit via a brazing material in accordance with another embodiment of the present invention;

[0014] FIG. 4 illustrates a cross-sectional view of the cutter assembly coupled to the drill bit via a pin protruding into the inner portion of the cutter assembly in accordance with yet another embodiment of the present invention; and

[0015] FIG. 5 illustrates a cross-sectional view of the cutter assembly coupled to the drill bit via a plurality of pins protruding into the sides of the cutter assembly in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION

[0016] The following discussion is presented to enable a person skilled in the art to make and use the invention. The general principles described herein may be applied to embodiments and applications other than those detailed below without departing from the spirit and scope of the present invention as defined by the appended claims. The present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

[0017] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods, and devices for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

[0018] FIG. 1 shows a perspective view of an exemplary embodiment of a drill bit of the present invention, shown generally at 100. Bit 100 may be any type of bit or composed of any material suitable for drilling operations, including, for example, a traditional drag bit, an impregnated diamond bit, an eccentric reamer, a bi-center reamer, a hole opener, a steel body bit or a hybrid combination bit. Drill bit 100 includes a bit body 101, which is rotatable around a bit axis 102 of the drill bit 100, and a cutting face 103, which is coupled to the bit body 101, on the side exposed to the formation. The bit body
may be coupled to a drill string (not shown) during operation. The cutting face 103 is shown to have one or more profiled blades 104, wherein each of the profiled blades 104 has a plurality of cutter assemblies 105 arranged in one or more rows. The cutter assemblies 105 are coupled to the profiled blades 104 and each cutter assembly 105 has a planar table 126. Each planar table 126 may be made from a highly abrasive material such as PDC or a thermally stable variant. Planar table 126 is preferably made from superhard materials. For example, planar table 126 may be made from impregnated diamond. During operation, this planar table 126 scours the rock formation as the drill bit 100 rotates. In conventional drill bits, the planar table wears down due to impact, heat damage and abrasive wear and will need to be replaced, thereby limiting the rate of penetration. In one embodiment of the present invention, the cutter assemblies 105 allow the planar table 126 to rotate (either intentionally or unintentionally) during drilling. The rotation of the planar table 126 may allow the planar table 126 to continuously present a different edge to contact the rock formation. The rotation of planar table 126 also significantly reduces localized thermal degradation of the cutter assembly 105 by reducing the time that any given portion of the planar table 126 is in contact with the rock formation. Planar table 126 may be selectively shaped to facilitate cutting the rock formation or minimize thermal degradation or abrasive wear, e.g., chamfered, rounded or of non-uniform thickness. Alternatively, or in addition to providing a rotatable planar table 126, cutter assembly 105 may include a dampering mechanism to reduce impact damage, provide self-balancing, and/or reduce the overloading of drill bit 100.

Although FIG. 1 shows a specific number of profiled blades 104 on the drill bit 100, it is understood by those skilled in the art that the drill bit 100 is not limited to the specific number of profiled blades 104 shown in FIG. 1, but that there may be one or more profiled blades 104 on the drill bit 100. Also, although FIG. 1 shows a plurality of cutter assemblies 105 on each of the profiled blades 104, it is understood by those skilled in the art that each of the profiled blades 104 has one or more cutter assemblies 105. Finally, although FIG. 1 shows a single row of cutter assemblies 105 located on each profiled blade 104, it is understood by those skilled in the art that the cutter assemblies 105 are not limited to one row on each profiled blade 104, but that there may be one or more rows of cutter assemblies 105 on each of the profiled blades 104. Exemplary embodiments of cutter assembly 105 are shown in FIGS. 2-5, discussed below.

FIG. 2 depicts a cross-sectional view of a cutter assembly coupled to the drill bit in accordance with one embodiment of the present invention. The present invention utilizes the drill bit 100 having at least one cutter assembly 105. The cutter assembly 105 comprises a cutter base 110, a cutter substrate 120 rotatably coupled to the cutter base 110, and a sleeve 140 which surrounds the periphery of the cutter base 110 and a majority of the periphery of the cutter substrate 120. The cutter assembly 105 may include a dampering mechanism 150, which may be located between the cutter base 110 and the drill bit 100. The dampering mechanism 150 may include a vibration/shock dampering component employing mechanical, electrical, or engineered materials to reduce the impact damage to the cutter assembly 105. As a result, the life of the cutter assembly 105 may be significantly increased. Accordingly, cutter assembly 105 may include a planar table 126 that is operable to rotate, dampering mecha-

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than the diameters of the outer portion 136 of the second bearing base 124 and the planar table 126. A lip 130 is preferably provided at the location where these two diameters meet. The lip 130 couples with the sleeve 140 to allow the cutter substrate 120, and hence the planar table 126, to freely rotate axially around a cutter body axis 132, yet remain securely fit within the sleeve 140.

[0024] In this embodiment, the sleeve 140 is substantially cylindrical in shape and comprises a first portion 142 and a second portion 144. The internal diameter of the first portion 142 of the sleeve 140 is large enough to allow the inner portion 134 of the second bearing base 124, the second bearing surface 122 and the cutter base 110 to fit within it. When using the optional dampening mechanism 150, the dampening mechanism 150 would also fit within the internal diameter of the first portion 142 of the sleeve 140. The internal diameter of the second portion 144 of the sleeve 140 is preferably sized to allow the outer portion 136 of the second bearing base 124, located above the lip 130, to fit within it; but not the inner portion 134 of the second bearing base 124, located below the lip 130, or the cutter base 110. Although this embodiment utilizes the mechanical means of using the lip 130 to securely fit the cutter substrate 120 within the sleeve 140 while still allowing the cutter substrate 120, and hence the planar table 126, to rotate around the cutter body axis 132, other mechanisms may be used to accommodate this rotatable feature without departing from the scope and spirit of the present invention. The length of sleeve 140 is selected to allow at least a portion of the planar table 126 to remain exposed to the rock formation for cutting purposes. The sleeve 140 can be made of any material, including titanium, carbide, stainless steel, high carbon steel, alloys of these listed metals, or any other material suitable for use in drilling operations.

[0025] The dampening mechanism 150 may be positioned between the cutter base 110 and the drill bit 100 or profiled blade 104, and can be placed at this position, or screwed into this position, of the sleeve 140. In this embodiment, a bellows spring is used as the dampening mechanism 150. Although a bellows spring is used as the dampening mechanism 150, any other mechanical, magnetic, or electrical mechanism or engineered materials may be used as the dampening mechanism 150 without departing from the scope and spirit of the present invention. Dampening mechanism 150 may be pre-loaded or selected such that it dampens forces exerted on the planar table 126, exceeding a selected amount. For example, the dampening mechanism 150 may activate when the force on the bit 100 is over approximately 1000 pounds force. As a result, the drill bit 100 may continuously adjust to compensate for abnormal loading, vibration and whirl, associated with the drill bit 100 or the drill string (not shown) instability. Although a 1000 pound force is used for commencing the dampening effect, any desired force can be selected, depending upon the selected rock formation or other factors, without departing from the scope and spirit of the present invention. Accordingly, dampening mechanism 150 may increase the longevity of the cutter assembly 105 by reducing the wear caused by impact.

[0026] The cutter assembly 105 may be positioned into a cutter pocket 160 located within the drill bit 100. The cutter assembly 105 may be coupled to the drill bit 100 via a variety of methods, including body welding, infiltration, friction lock, adhesive, brazing, threads, pin(s) or plug(s), some of which are illustrated in FIG. 3, FIG. 4 and FIG. 5.

[0027] FIG. 3 illustrates a cross-sectional view of the cutter assembly coupled to the drill bit via a brazing material in accordance with one embodiment of the present invention. The cutter assembly 105 is first positioned within the cutter pocket 160. A brazing material 165 is then used to braze the sleeve 140 of the cutter assembly 105 to the drill bit 100. The brazing material 165 which may be used includes non-ferrous filler materials or alloys, which include alloys of silver, tin, zinc, copper or any other suitable brazing material. Also, although the sleeve 140 is shown not to enclose the base of the dampening mechanism 150, or the cutter base 110 if the dampening mechanism 150 is not used, the sleeve 140 may enclose this area without departing from the scope and spirit of the present invention.

[0028] FIG. 4 illustrates a cross-sectional view of the cutter assembly coupled to the drill bit via a pin protruding into the inner portion of the cutter assembly in accordance with one embodiment of the present invention. In this embodiment, the sleeve 140 also encloses the base of the dampening mechanism 150, or the cutter base 110 if the dampening mechanism 150 is not used. The cutter assembly 105 is positioned within the cutter pocket 160, such that a pin 170 couples the drill bit 100 to the base of the sleeve 140. Although the pin 170 is used to couple the drill bit 100 to the base of the sleeve 140, other forms of attachment, including a plurality of pins 170, screws and other methods known in the art, may be utilized without departing from the scope and spirit of the present invention.

[0029] FIG. 5 illustrates a cross-sectional view of the cutter assembly attached to the drill bit via a plurality of pins protruding into the sides of the cutter assembly in accordance with one embodiment of the present invention. In this embodiment, the cutter assembly 105 is positioned within the cutter pocket 160, such that the pin or a plurality of pins 170 couple the drill bit 100 to the sleeve’s 140 sides. Although the pin or the plurality of pins 170 are used to couple the drill bit 100 to the sleeve’s 140 sides, other forms of attachment, including screws and other methods known in the art, may be utilized without departing from the scope and spirit of the present invention. Also, although the sleeve 140 is shown not to enclose the base of dampening mechanism 150, or the cutter base 110 if the dampening mechanism 150 is not used, the sleeve 140 may enclose this area without departing from the scope and spirit of the present invention.

[0030] Referring primarily to FIG. 2, the cutter assembly 105 of the present invention will allow the drill bit 100 to operate with a greater rate of penetration, even in hard rock formations. First, the drill bit 100 is disposed into a well bore (not shown) and adjacent to a formation (not shown). The drill bit 100 rotates and engages the formation e.g., by the weight applied on the drill bit 100. This weight applied on the drill bit 100 includes the weight of the drill string (not shown). During the drill bit’s 100 rotation, the planar table 126 of the cutter assemblies 105, located on the drill bit 100, crushes and scrapes formation material at the borehole’s corners and side walls as the profiled blades 104 (FIG. 1) roll and slide across the formation material at the borehole bottom as the drill bit 100 rotates under applied torque and weight on bit. As the planar table 126 cuts through the formations the cutter substrate 120, and hence the planar table 126, may continuously or intermittently rotate about the cutter body axis 132 such that its cutting edge, or the sharp portion of the planar table 126 exposed to the formation, is continually replenished.

[0031] This replenishment of the cutting edge of planar table 126 may allow for a number of benefits. For example, all
edges of the planar table 126 may wear nearly evenly before replacement is required, thereby prolonging its life. Moreover, as the cutter substrate 120 rotates, heat is dissipated so as to reduce localized thermal degradation to the cutter substrate 120 by reducing the time that a specific portion of the cutting edge is subjected to the formation, thereby also increasing its life. This rotation is caused by the forces acting from the formation, or may be caused electrically, via a motor, or magnetically. The mechanism and power supply for providing active rotation in this latter case may be contained within the drill bit 100 and/or the drill string. The cutter substrate 120 has a second bearing surface 122 which couples to the first bearing surface 114 of the cutter base 110. The location where these two bearing surfaces 114, 122 meet acts as a rotary bearing 128. The surface friction at this interface is minimized due to the surface and material of the bearing surfaces 114, 122, e.g., diamond tables.

0032 Dampening mechanism 150 may provide additional wear resistance to the planar table 126, such wear caused by impact. This dampening effect may be continuous or selectively activated, depending on the dampening mechanism 150 utilized. For example, a dampening mechanism 150 may be selected such that when the load on the planar table 126 exceeds a selected amount, such as about 1000 pounds force or greater, the dampening mechanism 150 may activate so as to reduce damage. By reducing damage to the cutter substrate 120 and prolonging its life, the rate of penetration greatly increases.

0033 There are several advantages associated with using the drill bit 100 comprising one or more cutter assemblies 105 of the present invention. One of the main advantages is that the life of the cutting surface of drill bit 100 is extended dramatically due to the reduction of damage caused by thermal degradation, abrasive wear and impact. As a result, drill bits 100, especially PDC bits, may be able to drill into harder, more abrasive formations with an improved penetration rate than previously possible. Furthermore, there is a possibility that the number of profiled blades 104 required to drill the formation may be reduced, thereby increasing the penetration rate. In addition, by minimizing the number of profiled blades 104, the number of total cutter assemblies 105 may also be reduced. Moreover, the overall drill bit 100 cost may be reduced due to fewer profiled blades 104 per drill bit 100.

0034 The cutting assembly of the present invention may utilize cylindrical cutters and retainers that are cylindrical and in line with the current industry standard. Accordingly, the present invention may be used with a wide variety of existing drill bits and drilling tools. Furthermore, dampening mechanism 150 may allow the cutter substrate 120 to absorb some impact when exposed to an abnormal load. As a result, the design of drill bit 100 may be simplified or otherwise improved. For example, the need for leaching cutters (not shown) may be eliminated. Furthermore, the cutter assembly 105 may become more cost effective. Moreover, the drill bit 100 may be self-balancing and may have an improved resistance to impact. In addition, the drill bit 100 may be configured in such a way so as to offer dampening in both directions, along the cutter body axis 132 or the cutter assembly 105. Accordingly, tensile stresses acting on the planar table 126, stresses which can cause the planar table 126 to delaminate from the second bearing base 124, may be significantly reduced. Although the main advantages and the benefits from those advantages have been mentioned above, one skilled in the relevant arts may recognize additional advantages and benefits that may be realized.

0035 Although the invention has been described with reference to specific embodiments, these descriptions are not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention will become apparent to persons skilled in the art upon reference to the description of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. It is therefore, contemplated that the claims will cover any such modifications or embodiments that fall within the true scope of the invention.

What is claimed is:

1. A cutter assembly for a drill bit, comprising:
   a planar table; and
   a cutter substrate coupled to the planar table, wherein the cutter substrate has a cutter body axis and wherein the planar table is operable to rotate about the cutter body axis.

2. The cutter assembly of claim 1, further comprising a rotary bearing operable to facilitate the rotation of the planar table.

3. The cutter assembly of claim 2, wherein the planar table is positioned on a cutting face of the drill bit and is operable to rotate in response to contact with a solid surface as the drill bit engages the solid surface.

4. The cutter assembly of claim 3, further comprising a dampening mechanism.

5. The cutter assembly of claim 4, wherein the cutter assembly is mounted on a profiled blade of the drill bit.

6. A cutter assembly for a drill bit, comprising:
   a planar table; and
   a dampening mechanism operable to reduce an impact force applied to the drill bit in response to contact between the planar table and a solid surface as the drill bit engages the solid surface.

7. The cutter assembly of claim 6, wherein the dampening mechanism is operable to provide self-balancing of the drill bit.

8. The cutter assembly of claim 6, wherein the dampening mechanism is operable to reduce overloading of the drill bit.

9. The cutter assembly of claim 6, wherein the dampening mechanism activates when the impact force exceeds a selected amount of force.

10. The cutter assembly of claim 9, further comprising a cutter substrate coupled to the planar table, wherein the cutter substrate has a cutter body axis and wherein the planar table is operable to rotate about the cutter body axis.

11. A method for drilling a formation, the method comprising the steps of:
   providing a drill bit comprising a cutter assembly, wherein the cutter assembly comprises a cutter substrate having a planar table operable to rotate axially about a cutter body axis and comprising a cutting surface;
   disposing the drill bit in a well bore adjacent to a formation;
   rotating the drill bit around a bit axis;
engaging a portion of the planar table against the formation to cut a portion of the formation; and rotating the planar table.

12. The method of claim 11, wherein the step of rotating the planar table further comprises reducing an amount of time a portion of the cutting surface of the planar table contacts the formation.

13. The method of claim 12, further comprising the step of dampening at least a portion of the impact on the cutter assembly resulting from the planar table engaging the formation.

14. The method of claim 13, wherein the step of rotating the planar table further comprises the step of allowing the planar table to circumvolve about the cutter body axis as the planar table contacts the formation.

15. The method of claim 14, further comprising the step of substantially evenly distributing abrasive wear across the cutting surface of the planar table during drilling.

16. A method for drilling a formation, the method comprising the steps of: providing a drill bit comprising a cutter assembly, wherein the cutter assembly comprises a planar table and a dampening mechanism; disposing the drill bit in a well bore adjacent to a formation; rotating the drill bit around a bit axis; engaging a portion of the planar table against the formation to cut a portion of the formation; and dampening at least a portion of the impact on the drill bit as the drill bit engages the formation.

17. The method of claim 16, wherein the step of dampening at least a portion of the impact on the drill bit further comprises the step of activating the dampening mechanism at a selected amount of force.

18. The method of claim 17, further comprising the step of rotating the planar table as the planar table engages the formation.

19. The method of claim 18, further comprising the step of self-balancing the drill bit.

20. The method of claim 19, further comprising the step of reducing the overloading of the drill bit.

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