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**WEAR RESISTANT MATERIAL AT THE SHIRTTAIL EDGE AND LEADING EDGE
OF A ROTARY CONE DRILL BIT****CROSS-REFERENCE TO RELATED APPLICATION**

[01] This application claims the benefit of United States Patent Application No. 12/896,406 filed October 1, 2010, entitled "Wear Resistant Material at the Shirttail Edge and Leading Edge of a Rotary Cone Drill Bit," the disclosure of which is hereby incorporated by reference in its entirety and to the maximum extent allowable by law. This application also claims the benefit of United States Patent Application No. 13/156,458 filed June 9, 2011, entitled "Wear Resistant Material at the Leading Edge of a Rotary Cone Drill Bit," the disclosure of which is hereby incorporated by reference in its entirety and to the maximum extent allowable by law.

BACKGROUNDTechnical Field of the Invention

[02] The present invention relates to earth boring bits, and more particularly to those having rotatable cutters, also known as rotary cone drill bits.

Description of Related Art

[03] Reference is made to Figures 1A, 1B, 2A and 2B, wherein Figures 1A and 1B each illustrate an isometric view of a prior art rotary cone drill bit 10 and Figures 2A and 2B each illustrate a cross-sectional view of a portion of the prior art rotary cone drill bit 10 of Figures 1A and 1B, respectively. A leg 12 depends from a body portion 14 of the drill bit 10. The leg 12 includes a bearing shaft 16 which extends in a downward and radial inward direction. The bearing shaft 16 includes a cylindrical bearing surface 18. A cutter cone 20 is mounted to the bearing shaft 16 and supported for rotation by the bearing surface 18. In an alternative implementation, the cutter cone 20 is supported for rotation on the bearing shaft 16 by a set of roller bearings. The shape and configuration of the cone 20, as well its rotatable attachment to the bearing shaft 16, is well known in the art. In sealed bearing implementations, the bearing (journal or roller) between the cone 20 and bearing shaft 16 is lubricated by a lubricant (such as a grease) that fills regions adjacent to the bearing as well as other passages 21 in the rotary cone drill bit in a manner well known by those skilled in the art. This lubricant is retained within the rotary cone drill bit through the use of, for example, a resilient seal in the form of an o-ring 22 positioned in a seal gland 24 between the inner cylindrical surface 26 near the base of the cone 20 and the outer cylindrical surface 28 near the

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base of the bearing shaft 16. The lubrication system further includes a pressure compensation assembly 27 installed within an opening 29 formed in an upper shoulder surface 25 of the leg 12. The opening 29 is coupled to the passage 21. Figures 1B and 2B illustrate an implementation wherein the opening 29 is formed exclusively in the shoulder surface 25. It will be understood, however, that the opening 29 may be formed partially in the shoulder surface 25 and partially in the outer (gage or shirrtail) surface 30 of the leg 12 (below shoulder surface 25). Still further, the opening 29 may be formed in the outer surface 30 of the leg.

[04] The outer surface 30 of the leg 12 terminates at a semicircular edge 32 proximal to the cone 20. The region of the leg 12 associated with the surface 30 is known in the art as the “shirrtail region,” and the edge 32 is known in the art as the “shirrtail edge.” The shirrtail edge 32 is provided where the terminal portion of the surface 30 (e.g., shirrtail surface or outer gage) transitions to an inside radial surface 34 oriented parallel to the base of the cone 20 (and perpendicular to the bearing shaft 16) and positioned at the base of the bearing shaft 16. On a rotary cone drill bit 10, one of the primary forms of bit failure can be traced back to shirrtail wear. In one form of such shirrtail wear, the shirrtail edge 32 wears down, the radial extent of the inside radial surface 34 is decreased by this wear, and the resilient o-ring 22 seal in sealed bearings is exposed. If the bearing is instead an open (non-sealed or air) bearing, the wearing of the shirrtail edge may expose the air bearing.

[05] The prior art teaches two methods for delaying shirrtail wear. Figure 3 illustrates a first method in which a layer of welded hardfacing material 40 is applied to the surface 30 extending along at least a portion of the shirrtail edge 32. The hardfacing material is typically a deposit of tungsten carbide hardmetal 40 applied to the surface 30. The material is typically pelletized tungsten carbide carried in a nickel welding medium. This solution does not work well when the rotary cone drill bit is run in a highly abrasive rock formation because the hardfacing material 40 wears down too quickly. It is primarily the welding medium, typically nickel, which accounts for the relative poor performance of the weld on material. Figure 4 illustrates a second method in which tungsten carbide inserts 42 are press-fit into holes 44 formed in the surface 30 near the shirrtail edge 32. While these inserts 42 provide better abrasion resistance (in comparison to the use of hardfacing material), the inserts 42 do not provide protection for the shirrtail edge 32. The reason for this is that the holes 44 must be located at some appreciable distance from the shirrtail edge 32 in order for the press-fit to function properly and peripherally retain the inserts 42. For example, a separation $d1$ of at least 0.125 inches is typically provided from the edge of the hole 44 to the shirrtail edge 32. Thus, the method of Figure 4 functions to primarily protect the shirrtail region near to, but not

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exactly at, the shirrtail edge 32. Furthermore, in order to be suitably retained, the press-fit inserts 42 must typically have a thickness t (with a corresponding depth of the hole 44) such that a ratio of the thickness of the insert to a diameter d' of the insert (where the inserts are round) or width w of the insert (with other shapes) exceeds about 0.5 (i.e., $t/d' \geq 0.5$; or $t/w \geq 0.5$).

[06] A need accordingly exists in the art to provide an improved method of protecting the shirrtail edge (e.g., shirrtail edge 32).

[07] With reference once again to Figures 1A, 1B, 2A and 2B, the outer surface 30 of the leg 12 (e.g., below shoulder surface 25) in the shirrtail region laterally terminates at a leading shirrtail edge 50 and a trailing shirrtail edge 52. The leading shirrtail edge 50 is especially susceptible to wear during operation of the rotary cone drill bit 10. The prior art teaches two methods for delaying wear of the leading shirrtail edge 50. Figure 5 illustrates a first method in which a layer of welded hardfacing material 40 is applied to the surface 30 extending along at least a portion of the leading shirrtail edge 50. The hardfacing material is typically a deposit of tungsten carbide hardmetal 40. The material is typically pelletized tungsten carbide carried in a nickel welding medium. This solution does not work well when the rotary cone drill bit is run in a highly abrasive rock formation because the hardfacing material 40 wears down too quickly. It is primarily the welding medium, typically nickel, which accounts for the relative poor performance of the weld on material. Figure 6 illustrates a second method in which tungsten carbide inserts 42 are press-fit into holes 44 formed in the surface 30 near the leading shirrtail edge 50. While these inserts 42 provide better abrasion resistance (in comparison to the use of hardfacing material), the inserts 42 do not provide protection for the leading shirrtail edge 50. The reason for this is that the holes 44 must be located at some appreciable distance from the leading shirrtail edge 50 in order for the press-fit to function properly and peripherally retain the inserts 42. For example, a separation d_2 of at least 0.125 inches is typically provided from the edge of the hole 44 to the leading edge 50. Thus, the method of Figure 6 functions to primarily protect the shirrtail region near to, but not exactly at, the leading shirrtail edge 50. Furthermore, in order to be suitably retained, the press-fit inserts 42 must typically have a thickness t (with a corresponding depth of the hole 44) such that a ratio of the thickness of the insert to a diameter d' of the insert (where the inserts are round) or width w of the insert (with other shapes) exceeds about 0.5 (i.e., $t/d' \geq 0.5$; or $t/w \geq 0.5$).

[08] Although not explicitly shown in Figures 5 and 6, the protection mechanisms shown could alternatively, or additionally, be provided on the leading side surface 54 of the leg

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12. This leading side surface 54 is adjacent the outer surface 30 of the leg 12 at the leading shirttail edge 50.

[009] A need thus exists in the art to also provide an improved method of protecting the leading shirttail edge (e.g., leading edge 50) and/or the leading side surface (e.g., leading side surface 54) of the shirttail (the latter of which is adjacent the outer surface (e.g., outer surface 30) of the leg at the leading shirttail edge).

[010] With reference once again to Figures 1A, 1B, 2A and 2B, the shoulder surface 25 of the leg 12 laterally terminates at a leading shoulder edge 51 and a trailing shoulder edge 53. The leading shoulder edge 51 is also susceptible to wear during operation of the rotary cone drill bit 10, more specifically when the bit 10 is being removed from the drill hole. This is because the shoulder edge 51 may have to function in a cutting-like or abrasive manner to remove formation materials in instances where the drilled hole has narrowed. The leading shoulder edge 51 and shoulder surface 25 are further susceptible to damage from formation material falling in the drill hole and having to be removed. Wear of the leading shoulder edge 51 and shoulder surface 25 can have adverse affects on the opening 29 and the pressure compensation assembly 27 installed within that opening 29 that perhaps lead to premature failure of the lubrication system.

[011] A need thus exists in the art to provide an improved method of additionally protecting the leading shirttail edge (e.g., leading shirttail edge 50) and/or leading shoulder edge (e.g., leading shoulder edge 51), and/or as well as the leading side surface of the leg (e.g., leading side surface 54). The improved methods of protection may be combined in any manner with further protection of the shoulder surface (e.g., shoulder surface 25). Said protection methods or mechanisms may be combined or on separate bits.

SUMMARY

[001] One or more of the improved protection mechanisms described herein may be selected for use on a rotary cone drill bit.

[002] In an embodiment, a rotary cone drill bit comprises: a body, a leg depending from the body, and a bearing shaft extending from the leg. The leg includes a surface edge. A bottom surface of a hard material plate having an edge is positioned with a substantially conforming surface of the leg where the edge of the hard material plate defines at least a portion of the surface edge of the leg. The bit may further include a cone mounted to the bearing shaft.

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[03] In an embodiment, a rotary cone drill bit comprises: a body, a leg depending from the body, and a bearing shaft extending from the leg. The bit may further include a cone mounted to the bearing shaft. The leg includes surface edges. A bottom surface of a hard material plate having an edge is positioned with a substantially conforming surface of the leg where the edge of the hard material plate defines at least a portion of one of the surface edges of the leg. The surface edge may be at a shirrtail edge or at a leading shirrtail edge or at a leading shoulder edge as well as some combination. More than one hard plate material may be positioned on a leg, at the same surface edge or at different surface edges. In addition or as an alternative, a hard plate material may be positioned on a substantially conforming surface of a shoulder surface and/or on the leading side surface of the shirrtail (which is adjacent the outer surface of the leg at the leading shirrtail edge).

[04] In an embodiment, a rotary cone drill bit comprises: a body, a leg depending from the body, and a bearing shaft extending from the leg. The leg includes surface edges. The edge may be associated with either (or both) an outer surface of the leg or a shoulder surface of the leg (above the outer surface). The edge may be semicircular or curved. The semicircular or curved edge may be proximal to a cone mounted to the bearing shaft. The edge may be one that is particularly or more susceptible to wear during operation of the drill bit. A hard material plate is positioned with a substantially conforming surface of the leg in a location in or by said outer surface of the leg. The outer surface may extend inwardly from the shirrtail edge. The outer surface may extend inwardly from the leading edge of the shirrtail. The outer surface may extend outwardly from the leading edge of the shirrtail. The outer surface may be defined by the lateral leading edge of the leg.

[05] In an embodiment, a rotary cone drill bit comprises: a body, a leg depending from the body, and a bearing shaft extending from the leg. The leg includes a surface that is subject to wear during operation of the bit. The surface may be associated with either (or both) an outer surface of the leg or a shoulder surface or a side surface of the leg (above the outer surface). A bottom surface of a hard material plate having an edge is positioned with a substantially conforming surface of the leg in a location where the edge of the hard material plate defines at least a portion of the surface of the leg. The location may be in and/or by a curved outer surface of the leg extending inwardly from the shirrtail edge. The location may be in and/or by a curved outer surface of the leg extending inwardly from the leading edge of the shirrtail. The location may be in and/or by the leading side surface of the leg extending outwardly from the leading edge of the shirrtail. The location may be in and/or by a leading edge of a shoulder.

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[06] In any of the foregoing embodiments, the bottom surface of the hard material plate may be attached by the adhesive material to a conforming floor surface formed in and/or by an outer gage surface of the leg and/or a leading surface of the leg and/or a shirrtail surface of the leg and/or a leading shoulder surface of the leg. The conforming floor surface may be formed in the outer gage surface of the leg by a slot provided in the outer gage surface and extending inwardly from an edge. The conforming floor surface may be formed in the leading surface of the leg by a slot provided in the leading surface and extending outwardly from the leading edge. The conforming floor surface may be formed in the shoulder surface of the leg by a slot provided in the shoulder surface and extending inwardly from the shirrtail edge. The conforming floor surface may be formed in the shoulder surface of the leg by a slot provided in the shoulder surface and extending inwardly from the leading shoulder edge.

[07] In any of the foregoing embodiments, the conforming surface to which attachment is made may comprise: a floor surface formed in or by an outer surface of the leg, a floor surface formed in or by a shoulder surface of the leg, a floor surface formed in or by a side surface of the leg (adjacent either the outer surface or shoulder surface), a floor surface of a slot formed in the outer surface of the leg, a floor surface of a slot formed in the shoulder surface of the leg, and/or a floor surface of a slot formed in the leading side surface of the leg (adjacent either the outer surface or shoulder surface).

[08] In any of the foregoing embodiments, the conforming surface to which attachment is made may include only a small portion or an extended portion. In any of the foregoing embodiments, the conforming surface to which attachment is made may comprise any combination of: a floor surface formed in or by an outer shirrtail surface of the leg, a floor surface formed in or by a leading side surface of the leg, a floor surface formed in or by a leading shoulder surface of the leg, a floor surface of a slot formed in the outer shirrtail surface of the leg, a floor surface of a slot formed in the leading side surface of the leg, and/or a floor surface of a slot formed in the leading shoulder surface of the leg.

[09] In any of the foregoing embodiments, the slot when formed may include only a small portion or an extended portion of the desired surface. In addition or as an alternative, the slot when formed may include a plurality of substantially flat (or non-flat) and adjacent (or neighboring) floor surfaces in which an insert with a conforming bottom surface is provided for each flat (or non-flat) floor surface. In some embodiments, inserts may be arranged in a tiled edge-to-edge configuration.

[010] In any of the foregoing embodiments, a material for positioning the hard material plate may comprise a flowable adhesive material interposed between the bottom

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surface of the hard material plate to the floor surface of the leg. That material may comprise, for example, a brazing material. That material may also combine one or more of solder, adhesives, resins, and the like. Various combinations of said materials may be used on a bit.

[011] In any of the foregoing embodiments, the hard material plate is made of a material or combination of materials that are more abrasion resistant than the material used to make the leg and/or shirrtail of the bit. For example, the hard material plate may comprise one or more of polycrystalline diamond compact, or be made of a material such as a tungsten carbide, or comprise a polycrystalline cubic boron nitride compact, or comprise an impregnated diamond segment. Thickness of any plate may in any range from 0.050 to 0.500 inches. With more than one hard material plate, various combinations of said hard material plates may be used on a bit. A plate can have any desired shape, such as but not limited to polygonal shape, circular shape, oval shape, and the like, and variations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[012] Other features and advantages of the invention will become clear in the description which follows of several non-limiting examples, with references to the attached drawings wherein:

[013] Figures 1A and 1B illustrate isometric views of a prior art rotary cone drill bit;

[014] Figures 2A and 2B illustrate cross-sectional views of a portion of a leg of the prior art rotary cone drill bit of Figure 1;

[015] Figure 3 illustrates application of a layer of hardfacing material extending along at least a portion of the shirrtail edge;

[016] Figure 4 illustrates the use of tungsten carbide inserts near the shirrtail edge;

[017] Figure 5 illustrates application of a layer of hardfacing material extending along at least a portion of the leading edge of the shirrtail;

[018] Figure 6 illustrates the use of tungsten carbide inserts near the leading edge of the shirrtail;

[019] Figures 7A and 7B illustrate isometric views of a rotary cone drill bit including protection mechanisms for the shirrtail edge and the leading edge of the shirrtail;

[020] Figure 8 illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a shirrtail edge protection mechanism;

[021] Figures 9 and 10 illustrate cross-sectional views of a portion of a leg of a rotary cone drill bit which include embodiments of a mechanism for protecting the leading edge of the shirrtail and shoulder;

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[022] Figures 11 and 12 illustrate isometric views of a portion of the leg and including protection mechanisms for the shirttail edge;

[023] Figure 13 illustrates an isometric view of a rotary cone drill bit including protection mechanisms for the shirttail edge and the leading edge of the shirttail;

[024] Figure 14 illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a shirttail edge protection mechanism;

[025] Figures 15 and 16 illustrate cross-sectional views of a portion of a leg of a rotary cone drill bit which include embodiments of a mechanism for protecting the leading edge of the shirttail;

[026] Figures 17 and 18 illustrate isometric views of a portion of the leg and including protection mechanisms for the shirttail edge;

[027] Figures 19 and 20 illustrate additional cross-sectional views of a portion of a leg of a rotary cone drill bit which include embodiments of a mechanism for protecting the leading edge of the leg at the shirttail and shoulder;

[028] Figure 21 illustrates an isometric view of a rotary cone drill bit including protection mechanisms for the leading edges of the leg at the shirttail and shoulder; and

[029] Figures 22, 23, 24 and 25 illustrate cross-sectional views of a portion of a leg of a rotary cone drill bit which include embodiments of a mechanism for protecting the leading edge of the leg at the shirttail and shoulder.

DETAILED DESCRIPTION OF THE DRAWINGS

[030] Reference is now made to Figures 7A and 7B that each illustrate an isometric view of a rotary cone drill bit 110 including protection mechanisms for the shirttail edge and the leading edge (also referred to as the lateral leading edge) of the shirttail as well as protection mechanisms for the leading edge of the leg. A leg 112 depends from a body portion 114 of the drill bit 110. The leg 112 includes a bearing shaft (not shown, see Figure 8 reference 116 or Figure 2B reference 16) which extends in a downward and radial inward direction. A cutter cone 120 is mounted to the bearing shaft and supported thereon for rotation. The outer surface 130 of the leg 112 terminates at a semicircular edge 132 proximal to the cone 120. In addition, outer gage or shirttail 130 of leg 112 (located at the gage of the bit) terminates at a semicircular edge 132 proximal to the cone 120 (Figure 7B). The region of the leg 112 associated with the surface 130 is known in the art as the “shirttail region,” and the edge 132 is known in the art as the “shirttail edge.” The outer surface 130 of the leg 112 (which may be referred to as outer gage or shirttail surface 130) laterally terminates at a

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leading shirttail edge 150 and a trailing edge 152 of the shirttail (also referred to as trailing shirttail edge 152). The lateral leading edge 150 and lateral trailing edge 152 of the shirttail comprise extensions of the shirttail edge 132 extending along the length of the leg 112. The shirttail region further includes a leading side surface 154 which is adjacent the outer surface 130 of the leg 112 at the leading shirttail edge 150. The leg 112 further includes a shoulder surface 125 (positioned above the outer surface 130 and angled inwardly from the outer surface 130). The shoulder surface 125 of the leg 112 laterally terminates at a leading shoulder edge 151 and a trailing shoulder edge 153. The lateral leading edge 151 and lateral trailing edge 153 of the shoulder comprise extensions of the shirttail edges 150 and 152, respectively, extending along the length of the leg 112 (and may be referred to as the lateral leading edge of the leg 112). The leg further includes a leading side surface 154 which is adjacent the outer surface 130 and shoulder surface 125 of the leg 112 at the leading shirttail edge 150 and leading shoulder edge 151.

[031] Although illustrated for example as including a sealed bearing system, it will be understood that the present invention is applicable to both sealed and non-sealed (air) bearing bits. Some of the illustrations show a sealed bearing system. The lubrication system includes a pressure compensation assembly 127 installed within an opening 129 formed in the upper shoulder surface 125 of the leg 112 (see, e.g., Figure 7B). Figure 7B illustrates an implementation wherein the opening 129 is formed exclusively in the shoulder surface 125. It will be understood, however, that the opening 129 may be formed partially in the shoulder surface 125 and partially in the outer surface 130 of the leg 112 (below shoulder surface 125). Alternatively, the opening 129 may be formed exclusively in the outer surface 130.

[032] To protect the shirttail edge 132, a slot 134 is provided in the outer surface 130 of the leg 112 extending inwardly from the shirttail edge 132, and a hard plate insert 136 is adhered to a floor surface within the slot 134 (Figure 7A). See, also, Figure 8. To protect the lateral leading edge 150 of the shirttail, a slot 138 is provided in the outer surface 130 of the leg 112 extending inwardly from the leading edge 150 of the shirttail, and a hard plate insert 140 is adhered to a floor surface within the slot 138. See, also, Figure 9. To protect the leading side surface 154, a slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the leading edge 150 of the shirttail, and a hard plate insert 144 is adhered to a floor surface within the slot 142. See, also, Figure 10. The slots may be milled or cast into the outer surface 130 and/or leading side surface 154 of the leg 112 at desired positions, specifically positions on the leg which are susceptible to wear during operation of

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the bit, and may have flat or curved floor surface geometries as desired and which conform with the bottom surfaces of the inserts 136, 140 and 144.

[033] Although the above described protection mechanisms are illustrated in Figure 7A, it will be understood that any one or more of the illustrated protection mechanisms may be selected for use on the rotary cone drill bit 110. Although Figure 7A illustrates the use of several hard plate inserts 136 along the shirttail edge 132, it will be understood that one slot 134 could instead be provided extending along all or a portion of the shirttail edge 132, with a single hard plate insert 136 adhered within the slot 134. Although Figures 7A and 7B illustrate the use of several hard plate inserts 140 along the leading edge 150 of the shirttail, it will be understood that one slot 138 could instead be provided extending along all or a portion of the leading edge 150 of the shirttail, with a single hard plate insert 140 adhered within the slot 138. Although Figures 7A and 7B illustrate the use of several hard plate inserts 144 along the leading edge 150 of the shirttail, it will be understood that one slot 142 could instead be provided extending along all or a portion of the leading edge 150 of the shirttail, with a single hard plate insert 144 adhered within the slot 142. In each of the foregoing implementations, the portion of the edge (shirttail edge 132 and/or leading shirttail edge 150) selected to receive protection would be that portion of the edge which is most susceptible to wear during operation of the rotary cone drill bit 110.

[034] Reference is now made to Figure 8 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a shirttail edge protection mechanism. In this embodiment, the slot 134 is provided in the outer surface 130 of the leg 112 extending inwardly from the shirttail edge 132. The slot 134 may be milled or cast into the outer surface 130 of the leg 112. The slot 134 is defined by a floor surface 160, a rear wall 162 and two side walls 164 (see, also, Figure 7A). The floor surface 160 may, for example, be a substantially flat surface, or alternatively a curved surface. The hard plate insert 136 is adhered within the slot 134. In a preferred embodiment, a bottom surface of hard plate insert is adhered to a substantially conforming floor surface 160 of the slot 134. The bottom surface of the insert may, for example, comprise a flat surface which conforms with the flat floor surface, or have a curved surface conforming to the curved floor surface. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of

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which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 8, but it will be understood that the adhesive material is present between the conforming bottom surface and floor surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate insert 136 has a thickness such that when adhered within the slot 134, a top surface 166 of the plate insert 136 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the outer surface 130 of the leg 112. Furthermore, the hard plate insert 136 is sized such that an edge 168 of the plate insert opposite the rear wall 162 of the slot 134 defines (or is coincident with or nearly coincident with) the shirttail edge 132. The hard plate insert 136 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirttail of the bit. In a preferred implementation, the hard plate insert is made of a material such as solid tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion.

[035] The shirttail edge 132 is provided where the terminal portion of the surface 130 transitions to an inside radial surface 192 oriented parallel to the base of the cone 120 (perpendicular to the bearing shaft 116) and positioned at the base of the bearing shaft 116. The hard plate inserts 136 function to protect against wearing of the shirttail edge 132 and erosion of the inside radial surface 192. Although a sealed bearing system is illustrated, it will be understood that edge protection in accordance with the present invention is applicable to both sealed and non-sealed (air) bearing bits.

[036] The hard plate inserts 136 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the shirttail edge 132). The hard plate inserts 136 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w < 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 136 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, e.g., Figure 4)).

[037] Figures 11 and 12 illustrate isometric views of a portion of the leg 130 and including protection mechanisms for the shirttail edge 132 as shown in Figure 8. A cone 120

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has been omitted from Figures 11 and 12, showing how the hard plate inserts 136 are positioned at the shirttail edge 132. Figures 11 and 12 further show how the slots 134 are provided in the outer surface 130 of the leg 112 extending inwardly from the shirttail edge 132. A portion 190 of the shirttail material remains at the floor surface 160 of each slot 134 (adjacent the inside radial surface 192), and it is at the floor surface 160 where adhesion (for example, through brazing) is made to the hard plate insert 136. In this way, the adhesive material is not externally exposed and subject to possible wear. The insert may have a thickness in the range of 0.050 to 0.500 inches.

[038] As shown in Figure 12, where the protection is desired to extend in a continuous manner along an extended length of the shirttail edge 132, the slot likewise extends in a continuous manner along that extended length of the edge 132. In one embodiment, the floor surface may curve with the radius of the bit, and thus the bottom surface of the one or more included inserts will have a conforming curve. In another embodiment, the slot is formed to include a plurality of substantially flat and adjacent floor surfaces 160, and a hard plate insert 136 with a conforming flat bottom surface is provided for each flat surface and inserts are arranged in a tiled edge-to-edge configuration (see, dotted line reference 137 indicating adjacent tile edges).

[039] Reference is now made to Figure 9 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the lateral leading edge of the leg, including the lateral leading edge of the shirttail. In this embodiment, the slot 138 is provided in the outer surface 130 of the leg 112 extending inwardly from the lateral leading edge 150 of the shirttail. The slot 138 may be milled or cast into the outer surface 130 of the leg 112. The slot 138 is defined by a floor surface 170, a rear wall 172 and two side walls 174 (see, also, Figure 7A). The hard plate insert 140 is adhered within the slot 138. In a preferred embodiment, a bottom surface of hard plate insert is adhered to the floor surface 170 of the slot 138. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 9, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The adhesive material preferably

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has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate insert 140 has a thickness such that when adhered within the slot 138, a top surface 176 of the plate insert 140 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the outer surface 130 of the leg 112. Furthermore, the hard plate insert 140 is sized such that an edge 178 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 150 (leading surface 154) of the shirrtail. The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

[040] The hard plate inserts 140 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 150). The hard plate inserts 140 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 140 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 4)).

[041] Reference is now made to Figure 10 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the lateral leading edge of the shirrtail. In this embodiment, the slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the lateral leading edge 150 of the shirrtail. The slot 142 may be milled or cast into the leading side surface 154 of the leg 112. The slot 142 is defined by a floor surface 180, a rear wall 182 and two side walls 184 (see, also, Figure 7A). The hard plate insert 144 is adhered within the slot 142. In a preferred embodiment, a bottom surface of hard plate insert is adhered to the floor surface 180 of the slot 142. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable

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between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. Because of drawing scale, the adhesive material is not explicitly shown in Figure 10, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The hard plate insert 144 has a thickness such that when adhered within the slot 142, a top surface 186 of the plate insert 144 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the leading side surface 154 of the leg 112. Furthermore, the hard plate insert 144 is sized such that edge 188 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 150 (outer surface 130) of the shirrtail. The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

[042] The hard plate inserts 144 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 150). The hard plate inserts 144 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 144 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 4)).

[043] Reference is now made to Figure 13 which illustrates an isometric view of a rotary cone drill bit 210 including protection mechanisms for the shirrtail edge and the leading edge of the shirrtail. A leg 212 depends from a body portion 214 of the drill bit 210. The leg 212 includes a bearing shaft (not shown, see Figure 14 reference 216) which extends in a downward and radial inward direction. A cutter cone 220 is mounted to the bearing shaft and

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supported thereon for rotation. The outer surface 230 of the leg 212 terminates at a semicircular edge 232 proximal to the cone 220. The region of the leg 212 associated with the surface 230 is known in the art as the “shirttail region,” and the edge 232 is also known as referred to as “shirttail edge.” The outer surface 230 of the leg 212 laterally terminates at a leading shirttail edge 250 and a trailing edge 252 of the shirttail. The leading edge 250 and a trailing edge 252 of the shirttail comprise extensions of the shirttail edge 232 extending along the length of the leg 212. The shirttail region further includes a leading side surface 254 which is adjacent the outer surface 230 of the leg 212 at the leading shirttail edge 250. Although illustrated for example as including a sealed bearing system, it will be understood that the present invention is applicable to both sealed and non-sealed (air) bearing bits.

[044] To protect the shirttail edge 232, a hard plate 236 is adhered to a floor surface 231 provided in or by the curved outer surface 230 of the leg 212 extending inwardly from the shirttail edge 232. See, also, Figure 14. To protect the leading edge 250 of the shirttail, a hard plate 240 is adhered to a floor surface 231 provided in or by the curved outer surface 230 of the leg 212 extending inwardly from the leading edge 250 of the shirttail. See, also, Figure 15. To protect the leading side surface 254, a hard plate 244 is adhered to a floor surface 231 provided in or by the leading side surface 254 of the leg 212 extending outwardly from the leading edge 250 of the shirttail. See, also, Figure 16. Although all three protection mechanisms are illustrated in Figure 13, it will be understood that any one or more of the protection mechanisms may be selected for use on the rotary cone drill bit 210. The floor surfaces 231 are preferably machined or cast into the outer surfaces of the shirttail region along the edge 232 and edge 250, and may have flat or curved surface geometries as desired and which conform with the bottom surfaces of the plates 236, 240 and 244.

[045] Although Figure 13 primarily illustrates the use of polygonal plates, it will be understood that the plates can have any desired shape (including circular shapes, oval shapes, and the like). Furthermore, as shown in Figure 13, the plates can be of different sizes, perhaps with size selection depending on placement position.

[046] Although Figure 13 illustrates the use of several hard plates 236 along the shirttail edge 232, it will be understood that one plate 236 could instead be provided extending along all or a portion of the shirttail edge 232. Although Figure 13 illustrates the use of several hard plates (e.g., plate 240) along the leading edge 250 of the shirttail, it will be understood that one plate 240 could instead be provided extending along all or a portion of the leading edge 250 of the shirttail. In each of the foregoing implementations, the portion of the edge (shirttail edge 232 and/or leading shirttail edge 250) selected to receive protection would be

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that portion of the edge which is most susceptible to wear during operation of the rotary cone drill bit 210.

[047] Reference is now made to Figure 14 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a shirttail edge protection mechanism. In this embodiment, the bottom surface 260 of the hard plate 236 is adhered to a substantially conforming floor surface 231 provided in or by the curved outer surface 230 of the leg 212 and extending inwardly from the shirttail edge 232. The plate 236 is further defined by a rear edge 262 and two side edges 264 (see, also, Figure 13). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially parallel surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 14, but it will be understood that the adhesive material is present between the bottom surface and the outer surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 236 is sized such that its front edge 268 defines (or is coincident with or is nearly coincident with) the shirttail edge 232. The thickness of the plate 236 may range from 0.050 to 0.500 inches. The hard plate 236 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirttail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[048] The shirttail edge 232 is provided where the terminal portion of the surface 230 transitions to an inside radial surface 292 oriented parallel to the base of the cone 220 (perpendicular to the bearing shaft 216) and positioned at the base of the bearing shaft 216. The hard plates 236 function to protect against wearing of the shirttail edge 232 and erosion of the inside radial surface 292. Although a sealed bearing system is illustrated, it will be understood that edge protection in accordance with the present invention is applicable to both sealed and non-sealed (air) bearing bits.

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[049] The hard plates 236 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the shirttail edge 232). The hard plates 236 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[050] Figures 17 and 18 illustrate isometric views of a portion of the leg 230 and including protection mechanisms for the shirttail edge 232 as shown in Figure 13. The cone 220 has been omitted from Figures 17 and 18 to show how the hard plates 236 are positioned at the shirttail edge. 232. It is at the floor surface 231 formed in or by outer surface 230 where adhesion (for example, through brazing) is made to the conforming bottom surface 260 of each hard plate 236. In this way, the adhesive material is not externally exposed and subject to possible wear.

[051] As shown in Figure 18, protection is desired to extend in a continuous manner along an extended length of the shirttail edge 232. In one embodiment, the floor surface may curve with the radius of the bit, and thus the bottom surface of the one or more included plates will have a conforming curve. In another embodiment, the floor surface is formed to include a plurality of substantially flat and adjacent floor surfaces 260, and a hard plate 236 with a conforming flat bottom surface is provided for each flat surface and plates are arranged in a tiled edge-to-edge configuration (see, dotted line reference 237 indicating adjacent tile edges).

[052] Reference is now made to Figure 15 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge of the shirttail. In this embodiment, the bottom surface 270 of the hard plate 240 is adhered to a substantially conforming floor surface 231 formed in or by the outer surface 230 of the leg 212 and extending inwardly from the leading shirttail edge 250. The plate 240 is further defined by a rear edge 272 and two side edges 274 (see, also, Figure 13). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 15, but it will

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be understood that the adhesive material is present between the bottom surface and the flattened surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 240 is sized such that its front edge 278 defines (or is coincident with, or is nearly coincident with) the leading edge 250 of the shirrtail. The thickness of the plate 240 may range from 0.050 to 0.500 inches. The hard plate 240 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[053] The hard plates 240 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 250). The hard plates 240 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[054] Reference is now made to Figure 16 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge of the shirrtail. In this embodiment, the bottom surface 280 of the hard plate 244 is adhered to a substantially conforming floor surface 231 formed in or by the leading surface 254 of the leg 212 and extending outwardly from the leading shirrtail edge 250. The plate 244 is further defined by a rear edge 282 and two side edges 284 (see, also, Figure 13). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 16, but it will

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be understood that the adhesive material is present between the bottom surface and the flattened surface on the leading side surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 244 is sized such that its front edge 288 defines (or is coincident with, or is nearly coincident with) the leading edge 250 of the shirttail. The thickness of the plate 244 may range from 0.050 to 0.500 inches. The hard plate 244 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirttail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[055] The hard plates 244 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 250). The hard plates 244 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[056] The illustration of protection being applied using slots and plates at the shirttail edge and/or leading shirttail edge as described is by way of example only; it being understood that said protection mechanisms may be applied to any edge of the bit that are susceptible to wear.

[057] Further illustrations for protection using plates at the lateral leading edge of the leg, including leading shoulder edge and/or leading shirttail edge are also provided by way of example only, it being understood that the protection mechanisms may be applied to any edge of the bit that are susceptible to wear (including shirttail edges and trailing edges).

[058] To protect the lateral leading edge 150 and surface 130 of the leg, a slot 138 is provided in the outer surface 130 of the leg 112 extending inwardly from the leading edge 150, and a hard plate insert 140 is adhered to a floor surface within the slot 138. See, also, Figure 9. To protect the lateral leading edge 150 and the leading side surface 154, a slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the leading edge 150

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of the shirttail, and a hard plate insert 144 is adhered to a floor surface within the slot 142. See, also, Figure 10. To protect the shoulder leading edge 151 and the leading side surface 154, a slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the shoulder leading edge 151, and a hard plate insert 144 is adhered to a floor surface within the slot 142. See, also, Figure 19. To protect the shoulder leading edge 151 and the shoulder surface 125, a slot 138 is provided in the shoulder surface 125 of the leg 112 extending inwardly from the leading edge 151, and a hard plate insert 140 is adhered to a floor surface within the slot 138. See, also, Figure 20. Such an installation on the surface 125, in some instances, may be impractical because of the size and positioning of the opening 129. The slots may be milled or cast into the outer surface 130, shoulder surface 125 and/or leading side surface 154 of the leg 112 at desired positions, specifically positions on the leg which are susceptible to wear during operation of the bit, and may have flat or curved floor surface geometries as desired and which conform with the bottom surfaces of the inserts 140 and 144.

[059] Multiple protection mechanisms are further illustrated in Figure 7B. It will be understood that any one or more of the illustrated protection mechanisms may be selected for use on the rotary cone drill bit 110. Although Figure 7B illustrates the use of several hard plate inserts 140 along the leading edge 150, it will be understood that one slot 138 could instead be provided extending along all or a portion of the leading edge 150, with a single hard plate insert 140 adhered within the slot 138. Although Figure 7B illustrates the use of several hard plate inserts 144 along the leading edge 150, it will be understood that one slot 142 could instead be provided extending along all or a portion of the leading edge 150, with a single hard plate insert 144 adhered within the slot 142. Although Figure 7B illustrates the use of a single hard plate insert 144 along the shoulder leading edge 151, it will be understood that multiple slots with multiple inserts could be provided and further that one slot 142 could be provided extending along all or a portion of the shoulder leading edge 151, with a single hard plate insert 144 adhered within the slot 142. Although Figure 7B illustrates the use of a single hard plate insert 140 along the shoulder leading edge 151, it will be understood that multiple slots with multiple inserts could be provided and further that one slot 138 could be provided extending along all or a portion of the shoulder leading edge 151, with a single hard plate insert 140 adhered within the slot 138. In each of the foregoing implementations, the portion of the edge (leading shirttail edge 150 and/or shoulder leading edge 151) selected to receive protection would be that portion of the edge which is most susceptible to wear during operation of the rotary cone drill bit 110.

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[060] Although Figure 7B primarily illustrates the use of polygonal plate inserts, it will be understood that the plate inserts can have any desired shape (including circular shapes, oval shapes, semi-circular shapes, and the like). Furthermore, the plate inserts can be of different sizes, perhaps with size selection depending on placement position.

[061] Reference is again made to Figure 9 which is also illustrative of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the lateral leading edge of the leg. In this embodiment, the slot 138 is provided in the outer surface 130 of the leg 112 extending inwardly from the lateral leading edge 150. The slot 138 may be milled or cast into the outer surface 130 of the leg 112. The slot 138 is defined by a floor surface 170, a rear wall 172 and two side walls 174 (see, also, Figure 7B). The hard plate insert 140 is adhered within the slot 138. In one or more embodiments, a bottom surface of hard plate insert is adhered to the floor surface 170 of the slot 138. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 9, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate insert 140 has a thickness such that when adhered within the slot 138, a top surface 176 of the plate insert 140 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the outer surface 130 of the leg 112. Furthermore, the hard plate insert 140 is sized such that an edge 178 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 150 (leading surface 154) of the shirrtail. The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

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[062] As before, hard plate inserts 140 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 150). The hard plate inserts 140 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 140 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 6)).

[063] Reference is again made to Figure 10 which is also illustrative of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the lateral leading edge of the leg. In this embodiment, the slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the lateral leading edge 150. The slot 142 may be milled or cast into the leading side surface 154 of the leg 112. The slot 142 is defined by a floor surface 180, a rear wall 182 and two side walls 184 (see, also, Figure 7B). The hard plate insert 144 is adhered within the slot 142. In one or more embodiments, a bottom surface of hard plate insert is adhered to the floor surface 180 of the slot 142. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. Because of drawing scale, the adhesive material is not explicitly shown in Figure 7B, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The hard plate insert 144 has a thickness such that when adhered within the slot 142, a top surface 186 of the plate insert 144 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the leading side surface 154 of the leg 112. Furthermore, the hard plate insert 144 is sized such that edge 188 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 150 (outer surface 130). The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten

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carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

[064] As described previously, the hard plate inserts 144 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 150). The hard plate inserts 144 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 144 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 6)).

[065] Reference is now made to Figure 19 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the shoulder lateral leading edge 151. In this embodiment, the slot 142 is provided in the leading side surface 154 of the leg 112 extending outwardly from the shoulder lateral leading edge 151. The slot 142 may be milled or cast into the leading side surface 154 of the leg 112. The slot 142 is defined by a floor surface 180, a rear wall 182 and two side walls 184 (see, also, Figure 7B). The hard plate insert 144 is adhered within the slot 142. In a preferred embodiment, a bottom surface of hard plate insert is adhered to the floor surface 180 of the slot 142. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. Because of drawing scale, the adhesive material is not explicitly shown in Figure 19, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The hard plate insert 144 has a thickness such that when adhered within the slot 142, a top surface 186 of the plate insert 144 is

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substantially flush with, or slightly exposed beyond, or slightly recessed below, the leading side surface 154 of the leg 112. Furthermore, the hard plate insert 144 is sized such that edge 188 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 151 (shoulder surface 125). The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

[066] The hard plate inserts 144, for example of Figure 19, have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 151). The hard plate inserts 144 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 144 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 6)).

[067] Reference is now made to Figure 20 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the lateral leading edge of the leg. In this embodiment, the slot 138 is provided in the shoulder surface 125 of the leg 112 extending inwardly from the lateral leading edge 151. The slot 138 may be milled or cast into the shoulder surface 125 of the leg 112. The slot 138 is defined by a floor surface 170, a rear wall 172 and two side walls 174 (see, also, Figure 7B). The hard plate insert 140 is adhered within the slot 138. In a preferred embodiment, a bottom surface of hard plate insert is adhered to the floor surface 170 of the slot 138. The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins,

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and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 20, but it will be understood that the adhesive material is present between the bottom surface and the floor surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate insert 140 has a thickness such that when adhered within the slot 138, a top surface 176 of the plate insert 140 is substantially flush with, or slightly exposed beyond, or slightly recessed below, the shoulder surface 125 of the leg 112. Furthermore, the hard plate insert 140 is sized such that an edge 178 of the plate insert opposite the rear wall 172 of the slot 138 defines (or is coincident with or nearly coincident with) the leading edge 151 (leading surface 154) of the shirrtail. The hard plate insert 140 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate insert is made of a material such as tungsten carbide, polycrystalline diamond compact (PDC), polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear.

[068] The hard plate inserts 140, for example of Figure 20, have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 151). The hard plate inserts 140 are thin inserts. In this case, a ratio of the thickness t of the insert to a width w of the insert is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the insert to the width w of the insert is substantially less than 0.5 (i.e., $t/w < 0.5$). Even more particularly, the ratio of the thickness t of the insert to the width w of the insert is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$). This is permitted because the hard plate inserts 140 are retained by adhesion to their bottom surface and not their peripheral edge (as is the case with the press-fit inserts used in the prior art (see, Figure 6)).

[069] Reference is now made to Figure 21 which illustrates an isometric view of a rotary cone drill bit 210 including protection mechanisms for the leading edges of the leg. A leg 212 depends from a body portion 214 of the drill bit 210. The leg 212 includes a bearing shaft (not shown, see Figure 2B reference 16) which extends in a downward and radial inward direction. A cutter cone 220 is mounted to the bearing shaft and supported thereon for rotation.

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The outer gage or shirrtail surface 230 of the leg 212 (located at the gage of the bit) terminates at a semicircular edge 232 proximal to the cone 220. The region of the leg 212 associated with the outer gage or shirrtail surface 230 is known in the art as the “shirrtail region,” and the edge 232 is known in the art as the “shirrtail edge.” The outer surface 230 of the leg 212 laterally terminates at a leading shirrtail edge 250 and a trailing shirrtail edge 252. The leading edge 250 and a trailing edge 252 of the shirrtail comprise extensions of the shirrtail edge 232 extending along the length of the leg 212. The leg 212 further includes a shoulder surface 225 (above the outer surface 230). The shoulder surface 225 of the leg 212 laterally terminates at a leading shoulder edge 251 and a trailing shoulder edge 253. The lateral leading edge 251 and lateral trailing edge 253 of the shoulder comprise extensions of the shirrtail edges 250 and 252, respectively, extending along the length of the leg 212 (and may be referred to as the lateral leading edge of the leg 212). The leg further includes a leading side surface 254 which is adjacent the outer surface 230 and shoulder surface 225 of the leg 212 at the leading shirrtail edge 250 and leading shoulder edge 251.

[070] The illustrated drill bit utilizes a sealed bearing system. The lubrication system includes a pressure compensation assembly 127 installed within an opening 129 formed in the upper shoulder surface 225 of the leg 212. Figure 20 illustrates an implementation wherein the opening 129 is formed exclusively in the shoulder surface 225. It will be understood, however, that the opening 129 may be formed partially in the shoulder surface 225 and partially in the outer surface 230 of the leg 212 (below shoulder surface 225). Alternatively, the opening 129 may be formed exclusively in the outer surface 230.

[071] To protect the leading edge 250 and outer surface 230 of the leg 212, a hard plate 240 is adhered to a floor surface 231 provided in or by the curved outer surface 230 of the leg 212 extending inwardly from the leading edge 250. See, also, Figure 22. To protect the leading edge 250 and the leading side surface 254, a hard plate 244 is adhered to a floor surface 231 provided in or by the leading side surface 254 of the leg 212 extending outwardly from the leading edge 250. See, also, Figure 23. To protect the shoulder leading edge 251 and the leading side surface 254, a hard plate 244 is adhered to a floor surface 231 provided in or by the leading side surface 254 of the leg 212 extending outwardly from the leading edge 251. See, also, Figure 24. To protect the leading edge 251 and shoulder surface 225 of the leg 212, a hard plate 240 is adhered to a floor surface 231 provided in or by the curved shoulder surface 225 of the leg 212 extending inwardly from the leading edge 251. See, also, Figure 25. Such an installation on the shoulder surface 225, in many instances, may be impractical because of the size and positioning of the opening 129.

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[072] Although multiple protection mechanisms are illustrated in Figure 21, it will be understood that any one or more of the illustrated protection mechanisms may be selected for use on the rotary cone drill bit 210. The floor surfaces 231 are preferably machined or cast into the outer surfaces of the shirttail region along the edge 250 and edge 251, and may have flat or curved surface geometries as desired and which conform with the bottom surfaces of the plates 240 and 244.

[073] Although Figure 21 primarily illustrates the use of polygonal plates, it will be understood that the plates can have any desired shape (including circular shapes, oval shapes, semi-circular shapes, and the like). Furthermore, the plates can be of different sizes, perhaps with size selection depending on placement position.

[074] Although Figure 21 illustrates the use of several hard plates 240 along the leading edge 250, it will be understood that one plate 240 could instead be provided extending along all or a portion of the leading edge 250. Although Figure 21 illustrates the use of several hard plates 244 along the leading edge 250, it will be understood that one plate 244 could instead be provided extending along all or a portion of the leading edge 250. Although Figure 21 illustrates the use of a single hard plate 244 along the leading edge 251, it will be understood that multiple plates 244 could instead be provided or that a single plate extending along all or a portion of the leading edge 251 could be used. Although Figure 21 illustrates the use of a single hard plate 240 along the leading edge 251, it will be understood that multiple plates 240 could instead be provided or that a single plate extending along all or a portion of the leading edge 251 could be used. In each of the foregoing implementations, the portion of the edge (edge 250 and/or edge 251) selected to receive protection would be that portion of the edge which is most susceptible to wear during operation of the rotary cone drill bit 210.

[075] Reference is now made to Figure 22 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge. In this embodiment, the bottom surface 270 of the hard plate 240 is adhered to a substantially conforming floor surface 231 formed in or by the outer surface 230 of the leg 212 and extending inwardly from the leading shirttail edge 250. The plate 240 is further defined by a rear edge 272 and two side edges 274 (see, also, Figure 21). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the

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disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 22, but it will be understood that the adhesive material is present between the bottom surface and the flattened surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 240 is sized such that its front edge 278 defines (or is coincident with, or is nearly coincident with) the leading edge 250 of the shirrtail. The thickness of the plate 240 may range from 0.050 to 0.500 inches. The hard plate 240 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[076] The hard plates 240, for example of Figure 22, have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 250). The hard plates 240 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[077] Reference is now made to Figure 23 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge. In this embodiment, the bottom surface 280 of the hard plate 244 is adhered to a substantially conforming floor surface 231 formed in or by the leading surface 254 of the leg 212 and extending outwardly from the leading shirrtail edge 250. The plate 244 is further defined by a rear edge 282 and two side edges 284 (see, also, Figure 21). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the

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disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 23, but it will be understood that the adhesive material is present between the bottom surface and the flattened surface on the leading side surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 244 is sized such that its front edge 288 defines (or is coincident with, or is nearly coincident with) the leading edge 250 of the shirrtail. The thickness of the plate 244 may range from 0.050 to 0.500 inches. The hard plate 244 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[078] The hard plates 244 have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 250). The hard plates 244 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[079] Reference is now made to Figure 24 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge of the shoulder 225. In this embodiment, the bottom surface 280 of the hard plate 244 is adhered to a substantially conforming floor surface 231 formed in or by the leading surface 254 of the leg 212 and extending outwardly from the leading shoulder edge 251. The plate 244 is further defined by a rear edge 282 and two side edges 284 (see, also, Figure 21). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication

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No. 2009/0038442, the disclosure of which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 13, but it will be understood that the adhesive material is present between the bottom surface and the flattened surface on the leading side surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 244 is sized such that its front edge 288 defines (or is coincident with, or is nearly coincident with) the leading edge 251. The thickness of the plate 244 may range from 0.050 to 0.500 inches. The hard plate 244 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[080] The hard plates 244, for example of Figure 24, have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 251). The hard plates 244 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[081] Reference is now made to Figure 25 which illustrates a cross-sectional view of a portion of a leg of a rotary cone drill bit which includes an embodiment of a protection mechanism for the leading edge. In this embodiment, the bottom surface 270 of the hard plate 240 is adhered to a substantially conforming floor surface 231 formed in or by the shoulder surface 225 of the leg 212 and extending inwardly from the leading edge 251. The plate 240 is further defined by a rear edge 272 and two side edges 274 (see, also, Figure 21). The means for adhering the bottom surface to the floor surface may, for example, comprise any suitable adhering material which is interposed between the substantially conforming (for example, parallel) surfaces including adhesive material flowable between the substantially conforming surfaces by capillary action such as a brazing material, solder, adhesives, resins, and the like (see, for example, U.S. Patent Application Publication No. 2009/0038442, the disclosure of

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which is hereby incorporated by reference in its entirety). Because of drawing scale, the adhesive material is not explicitly shown in Figure 25, but it will be understood that the adhesive material is present between the bottom surface and the flattened surface. The adhesive material preferably has a substantially uniform thickness between the conforming bottom surface and floor surface. The hard plate 240 is sized such that its front edge 278 defines (or is coincident with, or is nearly coincident with) the leading edge 251. The thickness of the plate 240 may range from 0.050 to 0.500 inches. The hard plate 240 is made of a material or combination of materials which are more abrasion resistant than the material used to make the leg and shirrtail of the bit. In a preferred implementation, the hard plate is made of a material such as tungsten carbide, PDC, polycrystalline cubic boron nitride compact impregnated diamond segment, and the like. These materials are superior to the traditional weld on tungsten carbide hardfacing known in the prior art because they are denser and are not as susceptible to abrasion and erosion. Again, the adhesive material in this implementation is not externally exposed and subject to possible wear. The conforming surfaces where adhesion takes place may curve, for example, with the radius of the bit, or have any selected curved configuration.

[082] The hard plates 240, for example of Figure 25, have a thickness t and width w (wherein the width is measured in a direction perpendicular to the leading edge 251). The hard plates 240 are thin inserts. In this case, a ratio of the thickness t of the plate to a width w of the plate is less than 0.5 (i.e., $t/w < 0.5$). More particularly, the ratio of the thickness t of the plate to the width w of the plate is substantially less than 0.5 (i.e., $t/w \ll 0.5$). Even more particularly, the ratio of the thickness t of the plate to the width w of the plate is less than 0.2 (i.e., $t/w < 0.2$), and may even be less than 0.1 (i.e., $t/w < 0.1$).

[083] It will be noted again that the slots and plate inserts described may be of any selected geometry thus allowing for the application of protection to complex surfaces of the bit. Tiling of the inserts edge-to-edge permits the application of protection to be extended continuously over a complex curved surface. Alternatively, a single insert with a complex curved bottom surface could be provided.

[084] The hard plates described may be of any selected geometry thus allowing for the application of protection to complex surfaces of the bit.

[085] The illustrations of protection being applied using slots and plates at the leading shoulder edge and/or leading shirrtail edge is by way of example only, it being understood that the protection mechanisms described may be applied to any edge of the bit that are susceptible to wear (including shirrtail edges and trailing edges).

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[086] Although preferred embodiments of the method and apparatus have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

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WHAT IS CLAIMED IS:

- 1 1. A rotary cone drill bit, comprising:
2 a body;
3 a leg depending from the body, wherein the leg includes a surface edge
4 a bearing shaft extending from the leg;
5 a cone mounted to the bearing shaft;
6 at least one hard material plate having an edge and a bottom surface;
7 an adhesive material attaching the bottom surface of the hard material plate to a
8 substantially conforming surface of the leg, wherein the edge of the hard material plate
9 defines at least a portion of the surface edge of the leg.
- 1 2. The bit of claim 1 wherein the adhesive material attaching the bottom surface of
2 the hard material plate comprises a flowable adhesive material interposed between the bottom
3 surface of the hard material plate and the conforming surface of the leg.
- 1 3. The bit of claim 2 wherein the flowable adhesive material is a brazing material.
- 1 4. The bit of claim 1 wherein the adhesive material is a brazing material.
- 1 5. The bit of claim 1 wherein the hard material plate has width w and a thickness t ,
2 wherein a ratio $t/w < 0.5$.
- 1 6. The bit of claim 1 wherein the hard material plate has width w and a thickness t ,
2 wherein a ratio $t/w < 0.2$.
- 1 7. The bit of claim 1 wherein the hard material plate has width w and a thickness t ,
2 wherein a ratio $t/w < 0.1$.
- 1 8. The bit of claim 1 wherein the hard material plate is made of solid tungsten
2 carbide.
- 1 9. The bit of claim 1 wherein the hard material plate is one of a polycrystalline
2 diamond compact or an impregnated diamond segment.
- 1 10. The bit of claim 1 wherein the hard material plate is a polycrystalline cubic
2 boron nitride compact.
- 1 11. The bit of claim 1 wherein the surface edge is a shirttail edge of the leg.

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1 12. The bit of claim 11 further comprising a slot formed in the leg extending from
2 the shirttail edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 13. The bit of claim 12 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 14. The bit of claim 13 wherein the flowable adhesive material is a brazing
2 material.

1 15. The bit of claim 12 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 16. The bit of claim 1 wherein the surface edge is a leading shirttail edge of the leg.

1 17. The bit of claim 16 further comprising a slot formed in the leg extending from
2 the leading shirttail edge, and wherein the conforming surface of the leg to which the bottom
3 surface of the hard material plate is attached is a floor surface of the slot.

1 18. The bit of claim 17 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 19. The bit of claim 18 wherein the flowable adhesive material is a brazing
2 material.

1 20. The bit of claim 17 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 21. The bit of claim 1 wherein the surface edge includes a leading side surface of
2 the leg extending from the leading edge of the shirttail.

1 22. The bit of claim 21 further comprising a slot formed in the surface edge, and
2 wherein the conforming surface of the leg to which the bottom surface of the hard material
3 plate is attached is a floor surface of the slot.

1 23. The bit of claim 22 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material

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3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 24. The bit of claim 23 wherein the flowable adhesive material is a brazing
2 material.

1 25. The bit of claim 22 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 26. The bit of claim 1 wherein the surface edge is a leading shirttail edge of the leg
2 and extending to an outer shirttail surface of the leg.

1 27. The bit of claim 26 further comprising a slot formed in the leg extending from
2 the surface edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 28. The bit of claim 27 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 29. The bit of claim 28 wherein the flowable adhesive material is a brazing
2 material.

1 30. The bit of claim 27 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 31. The bit of claim 1 wherein the surface edge is leading shirttail edge of the leg
2 and extending to a leading side surface of the leg.

1 32. The bit of claim 31 further comprising a slot formed in the leg extending from
2 the surface edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 33. The bit of claim 32 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 34. The bit of claim 33 wherein the flowable adhesive material is a brazing
2 material.

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1 35. The bit of claim 32 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 36. The bit of claim 1 wherein the surface edge is shoulder leading edge of the leg.

1 37. The bit of claim 36 further comprising a slot formed in the leg extending from
2 the surface edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 38. The bit of claim 37 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 39. The bit of claim 38 wherein the flowable adhesive material is a brazing
2 material.

1 40. The bit of claim 37 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 41. The bit of claim 1 wherein the surface edge is shoulder leading edge of the leg
2 and extending to a leading side surface of the leg.

1 42. The bit of claim 41 further comprising a slot formed in the leg extending from
2 the surface edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 43. The bit of claim 42 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 44. The bit of claim 43 wherein the flowable adhesive material is a brazing
2 material.

1 45. The bit of claim 42 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 46. The bit of claim 1 wherein the surface edge is shoulder leading edge of the leg
2 and extending to a shoulder surface of the leg.

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1 47. The bit of claim 46 further comprising a slot formed in the leg extending from
2 the surface edge, and wherein the conforming surface of the leg to which the bottom surface of
3 the hard material plate is attached is a floor surface of the slot.

1 48. The bit of claim 47 wherein the adhesive material attaching the bottom surface
2 of the hard material plate to the floor surface of the slot comprises a flowable adhesive material
3 interposed between the bottom surface of the hard material plate and the floor surface of the
4 slot.

1 49. The bit of claim 48 wherein the flowable adhesive material is a brazing
2 material.

1 50. The bit of claim 47 wherein the slot include a plurality of substantially flat and
2 adjacent floor surfaces.

1 51. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of the shirttail edge.

1 52. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of the leading edge.

1 53. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of the lateral leading edge.

1 54. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of a curved outer surface of the leg and extending inwardly from the shirttail edge.

1 55. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of a curved outer surface of the leg and extending inwardly from the leading edge of
3 the shirttail.

1 56. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of a curved outer surface of the leg and extending outwardly from the lateral leading
3 edge of the shirttail.

1 57. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of a outer surface of the leg and extending outwardly from the leading shoulder edge.

1 58. The bit of claim 1 wherein the edge of the hard material plate defines at least a
2 portion of a outer surface of the leg and extending inwardly from the leading shoulder edge.

1 59. The bit of claim 1 wherein the conforming floor surface is formed in or by an

2 outer gage surface of the leg.

1 60. The bit of claim 1 wherein the conforming floor surface is formed in the outer
2 gage surface of the leg by a slot provided in the outer gage surface and extending inwardly
3 from the leading edge.

1 61. The bit of claim 1 wherein the conforming surface is formed in or by a leading
2 surface of the leg.

1 62. The bit of claim 1 wherein the conforming floor surface is formed in the leading
2 surface of the leg by a slot provided in the leading surface and extending outwardly from the
3 leading edge.

1 63. The bit of claim 1 wherein the conforming floor surface is at a leading edge of
2 the leg adjacent the shoulder surface.

1 64. The bit of claim 63 wherein the shoulder surface further includes a pressure
2 compensator opening formed in the shoulder surface.

1 65. The bit of claim 1 wherein the conforming floor surface is at the leading edge of
2 the leg adjacent an outer gage surface.

1 66. The bit of claim 1 wherein the conforming floor surface is formed in or by the
2 shoulder surface of the leg.

1 67. The bit of claim 1 wherein the conforming floor surface is formed in the
2 shoulder surface of the leg by a slot provided in the shoulder surface and extending inwardly
3 from the leading edge.

1 68. The bit of claim 67 wherein the shoulder surface further includes a pressure
2 compensator opening formed in the shoulder surface.

1 69. The bit of claim 1 wherein the adhesive is not externally exposed and subject to
2 possible wear.

1 70. The bit of claim 1 wherein the adhesive material has a substantially uniform
2 thickness.

1 71. The bit of claim 1 wherein the hard material plate is made of a material or
2 combination of materials that are more abrasion resistant than the material used to make the leg
3 of the bit.