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O-RING SEAL FOR ROCK BIT BEARINGS

Field of the Invention

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This invention relates to an O-ring seal for retaining the lubricant around the journal bearings in a rock bit or drill bit for drilling oil wells or the like. More particularly, this invention relates to an O-ring seal comprising a surface having enhanced properties of reduced break-off friction that minimizes the occurrence of stick-slip, enhancing the service life of the O-ring seal and rock bit.

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Background of the Invention

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Heavy-duty drill bits or rock bits are employed for drilling wells in subterranean formations for oil, gas, geothermal steam, and the like. Such drill bits have a body connected to a drill string and a plurality, typically three, of hollow cutter cones mounted on the body for drilling rock formations. The cutter cones are mounted on steel journals or pins integral with the bit body at its lower end. In use, the drill string and bit body are rotated in the bore hole, and each cone is caused to rotate on its respective journal as the cone contacts the bottom of the bore hole being drilled. As such a rock bit is used for drilling in hard, tough formations, high pressures and temperatures are encountered.

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The total useful life of a drill bit in such severe environments is in the order of 20 to 200 hours for bits in sizes of about 6½ to 12½ inch diameter at depths of

1 about 5,000 to 20,000 feet that are operated at about 200
rpm. Useful lifetimes of about 65 to 150 hours are
typical. However, the useful life of drill bits that are
operated at higher revolutions such as 375 rpm, i.e.,
5 high-speed drill bits, is generally in the range of from
about 20 to 50 hours. The shortened useful life is often
due to the increased frictional heat produced in the bit
caused by the increased operating speed.

When a drill bit wears out or fails as a bore hole is
10 being drilled, it is necessary to withdraw the drill
string for replacing the bit. The amount of time required
to make a round trip for replacing a bit is essentially
lost from drilling operations. This time can become a
significant portion of the total time for completing a
15 well, particularly as the well depths become great. It is
therefore quite desirable to maximize the service life of
a drill bit in a rock formation. Prolonging the time of
drilling minimizes the time lost in "round tripping" the
drill string for replacing the bits. Replacement of a
20 drill bit can be required for a number of reasons,
including wearing out or breakage of the structure
contacting the rock formation.

One reason for replacing the rock bits include
failure or severe wear of the journal bearings on which
25 the cutter cones are mounted. These bearings are subject
to high pressure drilling loads, high hydrostatic
pressures in the hole being drilled, and high temperatures
due to drilling, as well as elevated temperatures in the
formation being drilled. Considerable development work
30 has been conducted over the years to produce bearing
structures and to employ materials that minimize wear and
failure of such bearings.

The journal bearings are lubricated with grease
adapted to such severe conditions. Such lubricants are a
35 critical element in the life of a rock bit. A successful
grease should have a useful life longer than other
elements of the bit so that premature failures of bearings

1 do not unduly limit drilling. Failure of lubrication can
be detected by generation of elevated pressure in the bit,
evidence of which can often be found upon examination of
a used bit. The high pressure is generated due to
5 decomposition of the oil in the grease, with consequent
generation of gas when lubrication is deficient and a
bearing overheats due to friction. Lubrication failure
can be attributed to misfit of bearings or O-ring seal
failure, as well as problems with a grease.

10 Pressure and temperature conditions in a drill bit
can vary with time as the drill bit is used. For example,
when a "joint" of pipe is added to the drill string,
weight on the bit can be relieved and slight flexing can
occur. Such variations can result in "pumping" of the
15 grease through O-ring seals, leading to loss of grease or
introduction of foreign abrasive materials, such as
drilling mud, that can damage bearing surfaces. One of
the consistent problems in drill bits is the inconsistency
of service life. Sometimes bits are known to last for
20 long periods, whereas bits which are apparently identical
operated under similar conditions may fail within a short
lifetime. One cause of erratic service life is failure of
the bearings. Bearing failure can often be traced to
failure of the seal that retains lubricant in the bearing.
25 Lubricant may be lost if the seal fails, or abrasive
particles of rock may work their way into the bearing
surfaces, causing excessive wear.

Rock bit O-rings are being called on to perform
service in environments which are extremely harsh. Modern
30 bits are being run at exceptionally high surface speeds,
sometimes more than 500 feet per minute, with cone speeds
averaging in the range of from 200 to 400 revolutions per
minute. One face of the O-ring is exposed to abrasive
drilling mud. The life of the O-ring may be significantly
35 degraded by high temperatures due to friction (as well as
elevated temperature in the well bore) and abrasion.

1 In order to provide a consistently reliable O-ring
seal for maintaining the lubricant within rock bits, it is
known to make the O-ring seal from a resilient elastomeric
composition displaying a desire degree of chemical
5 resistance, heat resistance, and wear resistance. O-ring
seals known in the art are constructed from resilient
elastomeric materials that, while displaying some degree
of chemical, heat, and wear resistance, ultimately limited
the service life of the rock bit by wearing away along the
10 surface during use.

 It is therefore desirable to provide a consistently
reliable O-ring seal for maintaining the lubricant within
a rock bit, that has a long useful life, is resistant to
crude gasoline and other chemical compositions found
15 within oil wells, has high heat resistance, is highly
resistant to abrasion, has a low coefficient of friction
against the adjacent seal surfaces to minimize heating and
wear, and that will not readily deform under load and
allow leakage of the grease from within the bit or
20 drilling mud into the bit.

Summary of the Invention

 There is, therefore, provided in practice of this
invention an improved O-ring seal for rock bit bearings.
25 A first embodiment of an improved O-ring seal comprises a
body formed from a highly-saturated nitrile (HSN)
resilient elastomeric composition. The HSN elastomeric
composition further comprises a multiplicity of low
friction wear resistant particles distributed uniformly
30 throughout the elastomeric composition. The particles may
have a rounded or non-rounded, i.e., angular,
configuration.

 The low friction wear resistant particles may be
selected from the group of materials including soft
35 metals, hard metals, ceramic-metal composites, and
ceramics. Preferred low friction wear resistant materials
include titanium carbide, tungsten carbide, silicon

1 carbide, cubic boron nitride, diamond, and diamond-like
graphite. A preferred low friction wear resistant
particle has an average particle size in the range of from
about 0.001 to 0.2 millimeters (0.0001 to 0.01 inches).
5 A particularly preferred elastomeric O-ring seal
composition comprises in the range of from 10 to 15 parts
by weight of the low friction wear resistant particles per
100 parts by weight of the elastomeric composition.

The O-ring seal comprises a body and surface formed
10 from the elastomeric material and low friction wear
resistant particle matrix. The O-ring surface is
subjected to stick-slip by rotational contact with an
adjacent sealing surface, causing material loss of the
elastomeric component at the O-ring surface. The loss of
15 the elastomeric component exposes the adjacent sealing
surfaces to the low friction wear resistant particles,
which form wear pads along the surface to isolate and
protect the elastomeric material from further stick-slip
related loss. In this manner the wear resistant particles
20 help to minimize material loss from occurring at the
O-ring surface, extending the life of the O-ring and the
rock bit.

25 Brief Description of the Drawings

A rock bit containing an O-ring seal constructed
according to the principles of this invention is
illustrated in semi-schematic perspective in FIG. 1 and in
partial cross-section in FIG. 2.
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1 Detailed Description

 A rock bit employing an O-ring seal constructed according to principles of this invention comprises a body 10 having three cutter cones 11 mounted on its lower end, as shown in FIG. 1. A threaded pin 12 is at the upper end of the body for assembly of the rock bit onto a drill string for drilling oil wells or the like. A plurality of tungsten carbide inserts 13 are pressed into holes in the surfaces of the cutter cones for bearing on the rock formation being drilled. Nozzles 15 in the bit body introduce drilling mud into the space around the cutter cones for cooling and carrying away formation chips drilled by the bit.

 O-ring seals are generally thought of as comprising a cylindrical inside diameter, outside diameter, and a cylindrical cross section. Accordingly, for purposes of reference and clarity, the figures used to describe the principles and embodiments of this invention have been created to illustrate an O-ring seal having a generally circular cross section. However, the principles of this invention are also meant to apply to O-ring seals having non-cylindrical cross sections, such as an elliptical cross section and the like. Therefore, it is to be understood that the principles of this invention may apply to O-rings having a circular or non-circular cross sections.

 FIG. 2 is a fragmentary, longitudinal cross-section of the rock bit, extending radially from the rotational axis 14 of the rock bit through one of the three legs on which the cutter cones 11 are mounted. Each leg includes a journal pin extending downwardly and radially, inwardly on the rock bit body. The journal pin includes a cylindrical bearing surface having a hard metal insert 17 on a lower portion of the journal pin. The hard metal insert is typically a cobalt or iron-based alloy welded in place in a groove on the journal leg and having a

1 substantially greater hardness than the steel forming the journal pin and rock bit body.

5 An open groove 18 is provided on the upper portion of the journal pin. Such a groove may, for example, extend around 60 percent or so of the circumference of the journal pin, and the hard metal insert 17 can extend around the remaining 40 percent or so. The journal pin also has a cylindrical nose 19 at its lower end.

10 Each cutter cone 11 is in the form of a hollow, generally-conical steel body having cemented tungsten carbide inserts 13 pressed into holes on the external surface. For long life, the inserts may be tipped with a polycrystalline diamond layer. Such tungsten carbide inserts provide the drilling action by engaging a
15 subterranean rock formation as the rock bit is rotated. Some types of bits have hard-faced steel teeth milled on the outside of the cone instead of carbide inserts.

20 The cavity in the cone contains a cylindrical bearing surface including an aluminum bronze insert 21 deposited in a groove in the steel of the cone or as a floating insert in a groove in the cone. The aluminum bronze insert 21 in the cone engages the hard metal insert 17 on the leg and provides the main bearing surface for the cone on the bit body. A nose button 22 is between the end of
25 the cavity in the cone and the nose 19 and carries the principal thrust loads of the cone on the journal pin. A bushing 23 surrounds the nose and provides additional bearing surface between the cone and journal pin. Other types of bits, particularly for higher rotational speed
30 applications, have roller bearings instead of the exemplary journal bearings illustrated herein. It is to be understood that an O-ring seal constructed according to principles of this invention may be used with rock bits comprising either roller bearings or conventional journal
35 bearings.

A plurality of bearing balls 24 are fitted into complementary ball races in the cone and on the journal

1 pin. These balls are inserted through a ball passage 26,
which extends through the journal pin between the bearing
races and the exterior of the rock bit. A cone is first
fitted on the journal pin, and then the bearing balls 24
5 are inserted through the ball passage. The balls carry
any thrust loads tending to remove the cone from the
journal pin and thereby retain the cone on the journal
pin. The balls are retained in the races by a ball
retainer 27 inserted through the ball passage 26 after the
10 balls are in place. A plug 28 is then welded into the end
of the ball passage to keep the ball retainer in place.
The bearing surfaces between the journal pin and the cone
are lubricated by a grease. Preferably, the interior of
the rock bit is evacuated, and grease is introduced
15 through a fill passage (not shown). The grease thus fills
the regions adjacent the bearing surfaces plus various
passages and a grease reservoir, and air is essentially
excluded from the interior of the rock bit. The grease
reservoir comprises a cavity 29 in the rock bit body,
20 which is connected to the ball passage 26 by a lubricant
passage 31. Grease also fills the portion of the ball
passage adjacent the ball retainer, the open groove 18 on
the upper side of the journal pin, and a diagonally
extending passage 32 therebetween. Grease is retained in
25 the bearing structure by a resilient seal in the form of
an O-ring 33 between the cone and journal pin.
Preferably, the O-ring is in a slightly V-shaped groove.

A pressure compensation subassembly is included in
the grease reservoir 29. The subassembly comprises a
30 metal cup 34 with an opening 36 at its inner end. A
flexible rubber bellows 37 extends into the cup from its
outer end. The bellows is held into place by a cap 38
with a vent passage 39. The pressure compensation
subassembly is held in the grease reservoir by a snap ring
35 41.

When the rock bit is filled with grease, the
bearings, the groove 18 on the journal pin, passages in

1 the journal pin, the lubrication passage 31, and the
grease reservoir on the outside of the bellows 37 are
filled with grease. If the volume of grease expands due
to heating, for example, the bellows 37 is compressed to
5 provide additional volume in the sealed grease system,
thereby preventing accumulation of excessive pressures.
High pressure in the grease system can damage the O-ring
seal 33 and permit drilling mud or the like to enter the
bearings. Such material is abrasive and can quickly
10 damage the bearings. Conversely, if the grease volume
should contract, the bellows can expand to prevent low
pressures in the sealed grease system, which could cause
flow of abrasive and/or corrosive substances past the
O-ring seal.

15 The bellows has a boss 42 at its inner end which can
seat against the cap 38 at one end of the displacement of
the bellows for sealing the vent passage 39. The end of
the bellows can also seat against the cup 34 at the other
end of its stroke, thereby sealing the opening 36. If
20 desired, a pressure relief check valve can also be
provided in the grease reservoir for relieving over-
pressures in the grease system that could damage the
O-ring seal. Even with a pressure compensator, it is
believed that occasional differential pressures may exist
25 across the O-ring of up to ± 150 psi (548 kilopascals).

To maintain the desired properties of the O-ring seal
at the pressure and temperature conditions that prevail in
a rock bit, to inhibit "pumping" of the grease through the
O-ring seal, and for a long useful life, it is important
30 that the O-ring seal be resistant to crude gasoline and
other chemical compositions found within oil wells, have
a high heat and abrasion resistance, have low rubbing
friction, and not be readily deformed under the pressure
and temperature conditions in a well which could allow
35 leakage of the grease from within the bit or drilling mud
into the bit.

1 Therefore, it is desired that the O-ring seal have a
modulus of elasticity at 100 percent elongation of from
850 to 1275 psi (6 to 9 megapascals), a minimum tensile
strength of 2300 psi (16 megapascals), elongation of from
5 200 to 350 percent, die C tear strength of at least 250
lb/in. (4.5 kilogram/millimeter), durometer hardness Shore
A in the range of from 75 to 85, and a compression set
after 70 hours at 100°C of less than about 18 percent and
preferably less than about 16 percent.

10 A variety of O-rings seals have been employed in such
rock bits. Such O-rings typically comprise acrylonitrile
polymers or acrylonitrile/butadiene copolymers. Other
components in the polymers are activators or accelerators
for the curing, such as stearic acid, and agents that add
15 to heat resistance of the polymer, such as zinc oxide and
curing agents. However, these synthetic rubbers typically
exhibit poor heat resistance and become brittle at
elevated temperatures after extended periods of time.
Additionally, such compounds often exhibit undesirably low
20 tensile strength and high coefficients of friction. Such
properties are undesirable for a seal in a rock bit, since
the high operating temperatures of the bit result in
frequent failure of the seal.

 Preferred O-ring seals can be formed from the group
25 of elastomeric compositions including fluoroelastomers,
carboxylated elastomers such as carboxylated nitriles, and
highly saturated nitrile (HSN) elastomers and the like.
A particularly preferred O-ring seal is made from an HSN
resilient elastomer material and is disclosed in U.S.
30 Patent Application Serial No. 07/884,657 that is assigned
to the same assignee as the present invention and is
hereby incorporated by reference. An exemplary
elastomeric composition may comprise per 100 parts by
weight of highly-saturated nitrile elastomer, furnace
35 black in the range of from 40 to 70 parts by weight,
peroxide curing agent in the range of from 7 to 10 parts
by weight, graphite in the range of from 10 to 20 parts by

1 weight, zinc oxide or magnesium oxide in the range of from
4 to 7 parts by weight, stearic acid in the range of from
0.5 to 2 parts by weight, and plasticizer up to about 10
parts by weight.

5 A mechanism of failure in a rock bit O-ring may be
characterized as stick-slip. As the elastomer of the
O-ring moves along the metal surface of the leg or cone,
the O-ring material momentarily sticks to the metal
surface. Almost instantly the elastomer then slips
10 relative to the metal. This making and breaking of bonds
between the elastomer and metal dissipates energy and
causes frictional heating. Furthermore, if too strong a
bond is formed between the elastomer and metal, some of
the elastomer may be removed from the O-ring, thereby
15 degrading the surface.

It is therefore desirable to minimize the amount of
sticking between the elastomer and metal. Such sticking
is minimized in practice of this invention by modifying
the surface of the O-ring without changing the bulk
20 properties of the main body of the O-ring.

In elastomeric materials the tensile modulus of the
elastomer, its tear strength and hardness are positively
correlated. When the hardness of the elastomer is
increased, one normally finds that the modulus and tear
25 strength are also increased. Hardness is therefore a
convenient means for comparing the properties of
elastomers. For a rock bit O-ring, it is desirable that
the durometer hardness of the O-ring is in the range of
from about 75 to 85 on the Shore A scale. Typically, the
30 hardness of the O-ring is about 80 Shore A. A hardness as
high as 85 may result in premature failure of an O-ring at
the same squeeze. Typically, in a rock bit, the squeeze
of the O-ring in the seal is from about 7.5 to 10.5
percent, preferably toward the high end of the range for
35 reliable sealing. It is desirable to maintain a squeeze
in about this range and a bulk hardness in the order of 78

1 to 83, but to also increase the surface hardness and hence
modulus and tear strength.

5 An O-ring seal constructed according to principles of
this invention comprises a body and a surface both formed
from an elastomeric composition of the type previously
described. The HSN elastomeric composition further
comprises a multiplicity of particles of low friction wear
resistant materials which are uniformly distributed
10 throughout the elastomeric composition forming an
elastomeric low friction particle matrix. The particles
can be rounded of high and/or low sphericity, or can be
non-rounded or angular. Rounded particles are preferred
because their interaction with an adjacent sealing surface
is believed to be less abrasive than non-rounded or
15 angular particles. The low friction wear resistant
particles are added to the elastomeric composition to
enhance the wear resistance of and reduce friction at the
surface of the O-ring seal.

Suitable low friction wear resistant particles may be
20 selected from group of materials including soft metallic
materials such as copper, bronze, brass and the like, or
hard metallic materials such as nickel, cobalt or the
like, or ceramic-metal composite materials such as
cemented tungsten carbide, titanium carbide and the like,
25 or may be selected from groups of ceramic materials such
as cubic boron nitride, diamond, diamond-like graphite,
silicon carbide and the like. A particularly preferred
low friction wear resistant material is titanium carbide.
It is desired that the average particle size of the
30 selected wear resistant material be in the order of from
about 0.001 to 0.2 millimeters (0.0001 to 0.01 inches).

The O-ring seal is constructed by combining low
friction wear resistant particles with the elastomeric
material and mixing the combination together until the low
35 friction wear resistant particles are uniformly
distributed throughout the composition. A preferred
elastomeric composition comprises in the range of from 10

1 to 15 parts by weight of the wear resistant particles per
100 parts by weight of the elastomeric composition. The
O-ring seal is formed and cured the same as when the wear
resistant particles are not present.

5 The completed O-ring seal is placed into position in
the rock bit with the seal surface in contact with
respective surfaces of the cone and the journal. As the
cone is rotated on the journal, the surface of the O-ring
seal is subjected to friction caused by the rotation on
10 the adjacent journal pin surface (a rock bit O-ring
typically stays stationary relative to the cone and slides
relative to the journal pin). The friction causes the
surface of the O-ring seal to heat and undergo stick-slip,
causing the rubber or elastomeric component of the O-ring
15 seal to wear away. As the elastomeric component of the
seal surface continues to wear, the entrapped particles of
the low friction wear resistant material begin to bear
against the rotating surface of the journal pin, forming
wear pads that serve to isolate the elastomeric component
20 of the O-ring seal surface from contact with an adjacent
sealing surface. This serves to both minimize the
occurrence of the "sticking" portion and maximize the
"slipping" portion of the stick-slip phenomena between the
O-ring surface and an adjacent sealing surface because the
25 low friction wear resistant particles, and not the
relatively higher friction elastomeric component, are
contacting the adjacent sealing surface. The O-ring seal
does this while maintaining a small sealing gap to prevent
excessive leakage. The reduction of stick-slip serves to
30 reduce material loss from the surface of the O-ring seal
and, thus extends the service life of the O-ring seal and
rock bit.

The friction between the wear resistant particles at
the surface of the O-ring seal and the adjoining surface
35 of the journal pin has been shown to be approximately one-
half of the friction of the elastomeric component against
the journal pin. Accordingly, the frictional heating

1 occurring at the surface of the O-ring seal is effectively
reduced by at least one-half through the incorporation of
the low friction wear resistant particles, extending the
service life of the seal and the rock bit. The low
5 friction wear resistant particles are not only resistant
to frictional or stick-slip related material loss caused
by rotation against adjacent sealing surfaces but are also
resistant to abrasive wear caused by exposure of the
O-ring surface to drilling fluid.

10 Although, limited embodiments of an improved O-ring
seal for rock bit bearings have been described and
illustrated herein. Many modifications and variations
will be apparent to those skilled in the art.
Accordingly, it is to be understood that within the scope
15 of the appended claims, the improved O-ring seal for rock
bit bearing according to principles of this invention may
be embodied other than as specifically described herein.

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1 **WHAT IS CLAIMED IS:**

1. A rotary cone rock bit for drilling subterranean formations comprising;

5 a bit body including a plurality of journal pins each extending from a leg portion of the bit and having a bearing surface;

 a cutter cone rotatably mounted on each journal pin and including a bearing surface;

10 a pressure-compensated grease reservoir in communication with such bearing surfaces;

 a grease in the grease reservoir and adjacent the bearing surfaces; and

 a dynamic O-ring seal for retaining the grease in the bearing comprising:

15 a body portion and a surface portion both formed from a resilient elastomeric composition and a multiplicity of low friction wear resistant particles uniformly distributed within the composition, the surface engaging a journal pin and
20 cone.

2. The rotary cone rock bit as recited in claim 1 wherein the O-ring seal comprises an array of the low friction wear resistant particles exposed at the surface
25 by wear of the elastomeric composition.

3. The rotary cone rock bit as recited in claim 1 wherein the elastomeric composition comprises a nitrile rubber.
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4. The rotary cone rock bit as recited in claim 1 wherein the particles of low friction wear resistant material are rounded or non-rounded.

35 5. The rotary cone rock bit as recited in claim 1 wherein the particles of low friction wear resistant material are selected from the group consisting of soft



1 metals, hard metals, ceramic-metal composites, and
ceramics.

5 6. The rotary cone rock bit as recited in claim 5
wherein the particles of low friction wear resistant
material are selected from the group of materials
consisting of titanium carbide, tungsten carbide, silicon
carbide, cubic boron nitride, diamond, and diamond-like
graphite.

10 7. The rotary cone rock bit as recited in claim 5
wherein the average particle size of the low friction wear
resistant material is in the range of from about 0.001 to
0.2 millimeters.

15 8. The rotary cone rock bit as recited in claim 5
wherein the elastomeric composition comprises in the range
of from 10 to 15 parts by weight of the wear resistant
particles per 100 parts by weight of the elastomeric
20 composition.

9. A rotary cone rock bit for drilling subterranean
formations comprising:

25 a bit body including a plurality of journal pins each
extending from a leg portion of the bit and having a
bearing surface;

a cutter cone rotatably mounted on each journal pin
and including a bearing surface;

30 a pressure-compensated grease reservoir in
communication with such bearing surfaces;

a grease in the grease reservoir and adjacent the
bearing surfaces;

35 a dynamic O-ring seal interposed between the cone and
the journal pin for retaining the grease in the bearing
comprising:

a body formed from a resilient elastomeric
matrix comprising an elastomeric material and a



1 multiplicity of low friction wear resistant
particles uniformly distributed throughout the
matrix selected from the group consisting of soft
metals, hard metals, ceramic-metal composites, and
5 ceramics; and

a surface comprising an array of such low
friction wear resistant particles exposed at the
surface by wear of the elastomeric matrix, forming
wear pads for contacting adjacent surfaces of the
10 journal pin and the cone.

10. The rotary cone rock bit as recited in claim 9
wherein the low friction wear resistant particles are
selected from the group of materials consisting of
15 titanium carbide, cemented tungsten carbide, cubic boron
nitride, diamond, diamond-like graphite, and silicon
carbide.

11. The rotary cone rock bit as recited in claim 10
20 wherein the low friction wear resistant particles have an
average particle size in the range of from 0.001 to 0.2
millimeters.

12. The rotary cone rock bit as recited in claim 11
25 wherein the elastomeric matrix comprises in the range of
from 10 to 15 parts by weight of the low friction wear
resistant particles per 100 parts of the elastomeric
material.

13. The rotary cone rock bit as recited in claim 12
30 wherein the low friction wear resistant particles are
rounded or non-rounded.