DISINTEGRATING COMPRESSION SET PLUG WITH SHORT MANDREL

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ABSTRACT

A compression set sealing element preferably 85A-95A TDI-Ester Polyurethane is compressed axially and retained against extrusion by CEM anti-extrusion rings. The compressed state of the sealing element is locked in by a degradable lock ring assembly. The mandrel is secured to an upper end of a slip cone and a breakable slip ring is secured by a wireline setting tool until the set position is reached. The slip ring breaks into segments that are pulled up the slip cone as the setting tool pushes on a sleeve to axially compress the sealing element and lock in the set. The sealing element is retained against extrusion by CEM anti-extrusion rings. When the setting tool is removed a ball seat is exposed for delivery of a ball to build pressure into the formation for fracturing. The entirety of the plug then disintegrates from well fluid exposure.
DISINTEGRATING COMPRESSION SET PLUG WITH SHORT MANDREL

RELATED APPLICATION

[0001] This application is a continuation in part of application Ser. No. 14/677,415 filed on Apr. 2, 2015.

FIELD OF THE INVENTION

[0002] The field of the invention is plugs that disintegrate and more particularly plugs with compression set sealing elements that disintegrate and that further have a shortened mandrel to the top of a slip cone to facilitate the disintegration.

BACKGROUND OF THE INVENTION

[0003] Fracturing is a process to enhance hydrocarbon delivery from a formation to a surface location. The fracturing is frequently a sequential process where a plug is set and a perforating gun that was run in with the plug is released from the plug and shot into the formation to create fractures. These fractures are then extended with high pressure slurry of proppant or typically mostly sand to open the perforation and hold them open by remaining in the perforation after the high pressure flow is cut off. The zone with the recently produced fractures from the perforating gun is sometimes isolated by dropping a ball on the seat of the plug to close off a passage through the plug so that pressure into the formation can be built up to deliver the proppant and further open or propagate the initially made fractures with the perforating gun. In general the process repeats until the entire formation is fractured at which time the completion for production is undertaken. However, before producing the plugs in aid of the fracturing need to be removed. The traditional way this was done was with a milling trip into the borehole to mill up all the plugs. This took a long time and required the milling debris to be removed from the borehole with circulation and/or with various debris retention devices.

[0004] Over time, various components of the plugs were made from materials that would disintegrate or otherwise fail over time after their purpose was served. This partial construction with disintegrating components still required a milling trip before production could start but the benefit was that the duration of the milling trip could be shortened as fewer components needed to be milled. For example U.S. 2011/0048743 had anchors that disintegrated with a seal assembly that needed milling out. In U.S. 2014/0318761 a lock for a hydrostatically set packer disintegrated to allow the packer to set. In U.S. Pat. No. 7,487,678 o-ring piston seals needed to disintegrate to enable some functions of a downhole valve. In U.S. 2007/0051521 a frac ball dropped onto a frac plug would disintegrate in an application of a retrievable frac packer. Disintegrating slips are shown in use with a ramp expanded sealing element are shown in U.S. 2013/0299185 and U.S. Pat. No. 8,959,504. In that same family a swage expanded seal that has a disintegrating agent in it is used as shown in FIGS. 9A and 9B of U.S. 2013/0300066. A seal that has a degradable layer is shown in U.S. 2013/0025849. For high pressure application the common approach to sealing has been pushing a seal assembly up a ramp into contact with a surrounding tubular as shown in U.S. Pat. Nos. 8,109,340 and 7,748,467.

[0005] Slips made from disintegrating materials are described in U.S. 2014/0262327. Grit applied to a slip with a smooth outer surface is discussed in U.S. 8,579,024. Slips that bite with an exterior surface roughness are described in WO2014170685A2.

[0006] What is needed and provided by the present invention is a packer or plug design that has degrading metallic components preferably made with controlled electrolytic materials (CEM) and sold under the brand In-talice by Baker Hughes Incorporated of Houston Tex. and described in U.S. 2011/0136707 and related applications filed the same day. The sealing element is preferably 85A-95A TDI-Ester Polyurethane that is axially compressed to increase in radial dimension. These materials can be used in a compression set packer assembly such as a Model D packer sold by Baker Hughes with modifications such as CEM anti-extrusion rings and locking system for the set. The mandrel is shortened to support the top of the cone for the slips so that there is less bulk to the plug and it can disintegrate faster. The inventors have discovered that sealing in fracking applications can be achieved with a compression set packing element that disintegrates. This goes contrary to the prevailing thinking that has focused on pushing sealing elements up ramps to get a seal or radially expanding rings from within with swage assemblies. Instead, the present invention combines the reliability of known plug designs that push slips out on a cone and then axially compress a sealing element and lock the set in a combination with materials that degrade to reduce or eliminate subsequent drilling out. To aid the disintegration process the mandrel is shortened to not go under the slip cone but instead to support the slip cone by its upper end so that there is less mandrel bulk to disintegrate with no sacrifice in structural integrity. Moreover, incorporating a disintegrating feature into a familiar and reliable basic plug layout gives confidence that the plug will set and properly anchor and seal without undue component complication or the need for high setting forces as would be needed in radial expansion with swages or axially forcing a seal assembly up a ramp to a sealing position. A slip ring is provided with external irregular surface that is coated with grit enhancing a grit as part of a slip assembly that can disintegrate. The application technique takes into account the sensitivity of disintegrating slip material to heat when the grit coating is adhered to the slip body. These and other aspects of the present invention will be more readily apparent to those skilled in the art from a review of the description of the preferred embodiment and the associated drawings while recognizing that the full scope of the invention is to be determined by the appended claims.

SUMMARY OF THE INVENTION

[0007] A compression set sealing element preferably 85A-95A TDI-Ester Polyurethane is compressed axially and retained against extrusion by CEM anti-extrusion rings. The compressed state of the sealing element is locked in by a degradable lock ring assembly. The mandrel is secured to an upper end of a slip cone and a breakable slip ring is secured by a wireline setting tool until the set position is reached. The slip ring breaks into segments that are pulled up the slip cone as the setting tool pushes on a sleeve to axially compress the sealing element and lock in the set. The sealing element is retained against extrusion by CEM anti-extrusion rings. When the setting tool is removed a ball seat is exposed for delivery of a ball to build pressure into the formation for fracturing. The entirety of the plug then disintegrates from well fluid exposure. A slip ring has external wickers and a
coating of grit is applied in a manner that preserves the strength of the disintegrating slip body for enhancement of grip.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 illustrates a section view of the disintegrating packer or plug in the run in position with the setting tool in support thereof;

[0009] FIG. 2 is a section view of a slip ring and cone in the run in position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0010] Referring to the FIG. 1, a slip ring 10 is an initial ring structure of slips that are circumferentially connected with breakable tabs that are not shown so that on setting which forces ring 10 onto cone 12 the resulting slips 14 separate from each other and wedge themselves against the surrounding borehole wall that is not shown. A wireline setting tool 16 of a type well known in the art and sold by Baker Hughes Incorporated as a Model E-4 supports the plug 18 to the desired subterranean location. The setting tool 16 pushes down on sleeve 20, which is a part of the setting tool 16 and comes out of the hole after the plug or packer is set, in the direction of arrow 22. At the same time the setting tool 16 pulls up on sub 24 until the shear stud 48 breaks which allows release of the setting tool 16 from the plug or packer 18. During setting the ring of individual slips 14 spits apart. Collet fingers 28 initially push up bottom sub 26 which takes it the slips 14 until they wedge against the borehole wall. The pushing down of sleeve 22 compresses the sealing element assembly 32 axially and allows the body lock ring assembly 34 to engage to prevent axial relaxation of sealing element assembly 32 that is now axially compressed to the point that its external radial dimension has increased to put surface 36 against the surrounding wellbore wall that is not shown. The internal dimension of the sealing element assembly conforms to the cylindrical shape of the outer wall of the mandrel 50 and does not change as the sealing element assembly 32 is axially collapsed. The axial compression of assembly 32 also extends the anti-extrusion rings 38 and 40 against the borehole wall to retain the sealing element 42, which can be a single sleeve or multiple sleeves, in between in the set position against the borehole wall. The seal rings 49 retain the sealing element 42 to the mandrel 50 to prevent swabbing-off the sealing element 42 during the installation of the plug in the borehole. These plugs are typically installed in horizontal wells and high rate fluid flow is used to push the plug to the desired location. This fluid flow exerts a force to pull the sealing element 42 off the Mandrel 50. Optionally an internal ring 44 can also be used under seal 42. Seal 42, ring 44, rings 38 and 40 or locking member 34 can also be made of polymers such as PC-PPDI, PC-MDI, PD-TDI, Ether-PPDI, Ether-MDI, Ether-TDI, Ester-PPDI, Ester-MDI, Ester-TDI or PAG. Ultimately pushing in the direction of arrow 22 and pulling in the direction of arrow 46 breaks the shear stud 48, pushes slips 14 up cone 12 and compresses seal 42 with the axial compression locked in with lock ring assembly 34. The setting tool 16 comes out through the plug mandrel 50. The plug mandrel 50 extends from the lock ring assembly 34 on the upper end to lower end 52 that has a thread 54 connected into upper end 50 of the cone 12. Thread 54 is the amount of extension of the mandrel 50 into the cone 12. Mandrel 50 and cone 12 have aligned passages for mounting to the setting tool 16. Alternatively the mandrel 50 can be integral with the cone 12.

[0011] Preferably the mandrel 50 including the lock ring assembly 34, the cone 12, the slips 14, internal ring 44, seal rings 49 and the anti-extrusion rings 38 and 40 as well as the bottom sub 26 are all made of a disintegrating material that is preferably CEM or another material that responds to existing or added well fluids or exposure over time to thermal or chemical inputs. Similarly the sealing assembly 32 is preferably made of 85A-95A TDI-Ester Polyurethane or a material that disintegrates under similar conditions as the balance of the plug or packer. Notably the mandrel 50 that stays in the hole is made short by ending it at the top of the cone 12 so that there is less of it to degrade so that the overall disintegration time is reduced.

[0012] In essence the slips 14 are not supported by the mandrel 50 but instead when set are wedged between the borehole wall that is not shown and the cone 12.

[0013] Those skilled in the art will appreciate that what is presented is a compression set plug that can be used in fracturing or other applications such as stimulation or acidizing, for example, by simply dropping a ball that is not shown onto a seat 60 that becomes exposed on removal of the setting tool 16. What was unexpected is the fact that degradable materials can be used in the context of a compression set sealing element with opposed degradable anti-extrusion rings and provide a reliable seal along with the degradability feature. After years of experimentation with designs that form as seal in place that degrades as well as designs that push seals up wedges or radially expand such seals while encountering a variety of issues that made such designs problematic for cost or operational reliability reasons, the present invention is in a sense back to the future in that the basic elements of a compression set packer have been fitted into an assembly that can reliably seal and disintegrate. Modifications have been further made to minimize the bulk of the packer or plug while retaining structural integrity to promote more rapid disintegration. The shorter mandrel also promotes the use of a larger bore through the plug or packer and exposes more surface area to well fluids to accelerate the disintegration process. Those skilled in the art will appreciate that the terms disintegrate, degrade, fail, dissolve or other terms are meant to be used interchangeably to denote an end to functional utility of the structure in the process of coming apart in pieces and ultimately disappearing or being circulated out to the surface.

[0014] Slip ring 10 is preferably made from magnesium but other materials such as chrome steel alloys nickel alloys; stainless alloys; carbide alloys; copper alloys; bronze; brass; aluminum and zinc to name some examples.

[0015] Ring 10 has a surface roughness 60 that can have a grit coating 62 for enhanced grip. The application process utilizes two wires of desired materials in a spray gun which facilitates a high current between them. The current causes the wires to melt while an air channel pushes the resulting grit onto the surface of the base metal. Parameters are set such that the particles create a rigid surface capable of producing an anti-slip feature, rather than a smooth, wear-resistant surface. This coating may be additive to provide a thicker layer ranging from, but not limited to, 0.010”-0.0009”.
The benefit of this process for the magnesium material is that this process does not create excessive surface temperature, which would typically burn the magnesium.

The ring 10 has scores 46 that allow the ring to break into segments as the swage 12 advances to then push the segments out further radially to engage the surrounding tubular.

The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

We claim:

1. A plug or packer assembly for subterranean use, comprising:
   a mandrel having a cylindrical outer surface;
   a slip assembly and an actuator for said slip assembly;
   a seal assembly on said cylindrical outer surface of said mandrel, said cylindrical outer surface of said mandrel representing a constant internal diameter of said seal assembly, said seal assembly actuated with axial compression of said seal assembly to axially collapse said seal assembly while maintaining said constant internal diameter and forcing said seal assembly by virtue of said axial collapse into contact with a surrounding borehole wall;
   wherein said mandrel, slip assembly, actuator for said slip assembly and said seal assembly comprise one or more materials that disintegrate over time at the subterranean location.

2. The assembly of claim 1, wherein:
   said mandrel supports said actuator for said slip assembly adjacent an upper end of said actuator for said slip assembly.

3. The assembly of claim 1, wherein:
   said mandrel terminates within said actuator for said slip assembly adjacent an upper end of said actuator for said slip assembly.

4. The assembly of claim 1, wherein:
   said mandrel further comprises a disintegrating locking member to hold the axially compressed position of said seal assembly.

5. The assembly of claim 4, wherein:
   said seal assembly further comprises at least one anti-extrusion ring on at least one end of said seal assembly, said anti-extrusion ring comprises a disintegrating material.

6. The assembly of claim 5, wherein:
   said at least one anti-extrusion ring comprises a plurality of anti-extrusion rings with at least one disposed on each of opposed ends of said seal assembly.

7. The assembly of claim 1, wherein:
   said seal assembly comprises a polymer.

8. The assembly of claim 1, wherein:
   said mandrel, slip assembly and actuator for said slip assembly comprises a controlled electrolytic material (CEM).

9. The assembly of claim 4, wherein:
   said locking member comprises a controlled electrolytic material (CEM).

10. The assembly of claim 6, wherein:
    said anti-extrusion rings comprise a controlled electrolytic material (CEM).

11. The assembly of claim 1, wherein:
    said seal assembly comprising a seal having the shape of a sleeve with an internal ring between said mandrel and an inside surface of said sleeve, said internal ring comprises a disintegrating material.

12. The assembly of claim 11, wherein:
    said internal ring comprises a polymer.

13. The assembly of claim 1, wherein:
    said actuator for said slip assembly comprising a cone with a cone passage therethrough, said mandrel having a mandrel passage therethrough that aligns with said cone passage.

14. The assembly of claim 13, wherein:
    said mandrel is threaded to a top of said cone and said thread represents the extension of said mandrel into said cone or said mandrel is made integral with said cone.

15. The assembly of claim 6, wherein:
   said seal assembly comprises a polymer further comprising at least one from a group comprising: PC-PDDI, PC-MDI, PD-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI or PGA and TDI-Ester Polyurethane.

16. The assembly of claim 15, wherein:
   said mandrel, slip assembly and actuator for said slip assembly comprises a controlled electrolytic material (CEM).

17. The assembly of claim 16, wherein:
   said locking member comprises a controlled electrolytic material (CEM) or a polymer further comprising at least one from a group comprising: PC-PDDI, PC-MDI, PD-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI or PGA and TDI-Ester Polyurethane.

18. The assembly of claim 17, wherein:
   said anti-extrusion rings comprise a controlled electrolytic material (CEM) or a polymer further comprising at least one from a group comprising: PC-PDDI, PC-MDI, PD-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI or PGA and TDI-Ester Polyurethane.

19. The assembly of claim 18, wherein:
   said seal assembly comprising a seal having the shape of a sleeve with an internal ring between said mandrel and an inside surface of said sleeve, said internal ring comprises disintegrating material.

20. The assembly of claim 19, wherein:
   said internal ring comprises a polymer further comprising at least one from a group comprising: PC-PDDI, PC-MDI, PD-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI or PGA and TDI-Ester Polyurethane.

21. The assembly of claim 1, wherein:
   said disintegration over time occurs from exposure to naturally or artificially created conditions at the subterranean location.

22. The assembly of claim 1, wherein:
   said seal assembly comprises a polymer.

23. The assembly of claim 7 wherein:
   said polymer comprises at least one from a group comprising: PC-PDDI, PC-MDI, PD-TDI, Ether-PDDI, Ether-MDI, Ether-TDI, Ether-PDDI, Ether-MDI, Ether-TDI or PGA and TDI-Ester Polyurethane.
24. The assembly of claim 4, wherein:
said polymer comprises at least one from a group comprising: PC-PPDI, PC-MDI, PD-TDI, Ether-PPDI, Ether-MDI, Ether-TDI, Ether-PPDI, Ester-MDI, Ester-TDI or PGA and TDI-Ester Polyurethane.

25. The assembly of claim 12, wherein:
said polymer comprises at least one from a group comprising: PC-PPDI, PC-MDI, PD-TDI, Ether-PPDI, Ether-MDI, Ether-TDI, Ether-PPDI, Ester-MDI, Ester-TDI or PGA and TDI-Ester Polyurethane.

26. The assembly of claim 6, wherein:
said anti-extrusion rings comprise at least one from a group comprising: PC-PPDI, PC-MDI, PD-TDI, Ether-PPDI, Ether-MDI, Ether-TDI, Ether-PPDI, Ester-MDI, Ester-TDI or PGA and TDI-Ester Polyurethane.

27. The assembly of claim 11, wherein:
said internal ring comprises a controlled electrolytic material (CEM).

28. The assembly of claim 1, wherein:
said seal assembly further comprises at least one disintegrating seal ring adjacent at least one end of a sealing element.

29. The assembly of claim 28, wherein:
said at least one seal ring comprises opposed seal rings adjacent opposed ends of said sealing element, said seal rings further comprising a controlled electrolytic material (CEM).

30. A well treatment method, comprising:
deploying the plug or packer of claim 1 to isolate a portion of a borehole;
applying pressure against said plug or packer.

31. The method of claim 30, comprising:
allowing said plug or packer to disintegrate after said applying pressure.

32. The assembly of claim 1, wherein:
said slip assembly further comprises a roughened outer surface coated with at least one layer of grip enhancing grit.

33. The assembly of claim 32, wherein:
said grit comprises melted particles blown onto said outer surface.

34. A method of applying a grit coating to a downhole component to enhance gripping capability comprising:
providing wires in a spray gun;
disposing said wires in a fluid channel;
running current through said wires;
creating the grit by causing the wires to melt with said current in the fluid channel;
delivering the resulting grit onto the surface of the base metal.

35. The method of claim 34, comprising:
limiting heat applied to the component with fluid driving the grit.

36. The method of claim 34, comprising:
applying the grit to a roughened outer surface of the component which further comprises at least one slip.