Methods and Systems for Wiping Surfaces When Performing Subterranean Operations

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Abstract

Improved darts and methods of using these darts in subterranean wells are disclosed. The improved dart comprises a foam portion and a rubber portion coupled to the foam portion. A dart nose is coupled to at least one of the foam portion and the rubber portion. The foam portion and the rubber portion are configured to interface with an inner surface of at least one of a well bore wall, a pipe, and a casing string.
METHODS AND SYSTEMS FOR WIPING SURFACES WHEN PERFORMING SUBTERRANEAN OPERATIONS

BACKGROUND

[0001] The present disclosure generally relates to subterranean operations. More particularly, the present disclosure relates to improved darts and methods of using these darts in subterranean wells.

[0002] During the drilling and construction of subterranean wells, casing strings (“casing”) are generally introduced into the well bore. To stabilize the casing, a cement slurry is often pumped downwardly through the casing, and then upwardly into the annulus between the casing and the walls of the well bore. One concern regarding this process is that, prior to the introduction of the cement slurry into the casing, the casing generally contains a drilling fluid or some other servicing fluid that may contaminate the cement slurry. To prevent this contamination, a plug, often referred to as a cementing plug or a “bottom” plug, may be placed into the casing ahead of the cement slurry as a boundary between the two. The plug may perform other functions as well, such as wiping fluid from the inner surface of the casing as it travels through the casing, which may further reduce the risk of contamination.

[0003] Similarly, after the desired quantity of cement slurry is placed into the well bore, a displacement fluid is commonly used to force the cement into the desired location. To prevent contamination of the cement slurry by the displacement fluid, a “top” cementing plug may be introduced at the interface between the cement slurry and the displacement fluid. This top plug also wipes cement slurry from the inner surfaces of the casing as the displacement fluid is pumped downwardly into the casing. Sometimes a third plug may be used, for example, to perform functions such as preliminarily calibrating the internal volume of the casing to determine the amount of displacement fluid required, or to separate a second fluid ahead of the cement slurry (e.g., where a preceding plug may separate a drilling mud from a cement spacer fluid, the third plug may be used to separate the cement spacer fluid from the cement slurry).

[0004] When performing subterranean operations, it may be desirable to keep different fluids separate and wipe the drillpipe or tubing string clean of cement, fluids or debris. Typically, the methods used involve a positive displacement plugging device, often referred to as a “dart.” Typically, rubber or foam darts are used when performing subterranean operations. However, both rubber darts and foam darts have certain drawbacks.

[0005] Rubber darts generally comprise two or more rubber “fins” that flare outwardly from a mandrel or stem. Such fins are generally sized to engage the inside wall of the pipe in which they are deployed. Because its fins prevent a dart from free falling to the plug, a pressure differential, or otherwise downward flow of fluid, usually is applied to force the dart to the plug. It is often desirable for the dart to pass through restrictions such as, for example, mechanical setting tools, diverters and liner running tools. However, rubber darts are not typically well suited for passing through such restrictions. Specifically, once passed through a restriction, rubber darts often experience a reduction in wiping efficiency. For instance, when a rubber dart that has passed through a restriction is used to clean cement in a casing it often leaves behind a large amount of cement.

[0006] Foam darts, such as those disclosed in U.S. Pat. No. 6,973,966, have a high parting stretch ratio compared to the conventional molded rubber darts, which means they can pass through small restrictions without a reduction in their cleaning efficiency. While the foam darts typically have a higher wiping efficiency, they also suffer from some disadvantages. For instance, the foam darts typically do not expand to their original size fast enough after passing through a restriction. Accordingly, after passing through a restriction and while collapsed, the foam darts may not wipe the casing effectively. Additionally, once a foam dart is collapsed due to passage through a restriction and before it expands to its original size it may not be in contact with the inner surface of the casing. As a result, the foam dart may free fall to the bottom of the casing string causing it to “land” early.

SUMMARY

[0007] The present disclosure generally relates to subterranean operations. More particularly, the present disclosure relates to improved darts for use in subterranean wells.

[0008] In one exemplary embodiment, the present disclosure is directed to a dart comprising: a foam portion; a rubber portion coupled to the foam portion; and a dart nose coupled to at least one of the foam portion and the rubber portion wherein the foam portion and the rubber portion are configured to interface with an inner surface of at least one of a well bore wall, a pipe, and a casing string.

[0009] In another exemplary embodiment, the present disclosure is directed to a method of cleaning a restriction in a casing comprising: placing a dart in the restriction; wherein the dart comprises a foam portion coupled to a rubber portion; passing the dart through the restriction; wherein at least one of the foam portion and the rubber portion cleans an inner surface of the restriction; and directing the dart out of the restriction to a wider portion of the casing; wherein a diameter of the wider portion of the casing exceeds a diameter of the restriction; and wherein the rubber portion interfaces with an inner surface of the wider portion of the casing before the foam portion interfaces with an inner surface of the wider portion of the casing.

[0010] The features and advantages of the present invention will be apparent to those skilled in the art from the description of the preferred embodiments which follows when taken in conjunction with the accompanying drawings. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These drawings illustrate certain aspects of some of the embodiments of the present invention, and should not be used to limit or define the invention.

[0012] FIG. 1 is a perspective view of a composite dart in accordance with one embodiment of the present invention.

[0013] FIG. 2 is a side view of the foam portion of a composite dart in accordance with an embodiment of the present invention.

[0014] FIG. 3 is a side view of the foam portion of a composite dart in accordance with another embodiment of the present invention.

[0015] FIGS. 4A-4C depict a schematic showing a composite dart as it passes through a workstring in accordance with an embodiment of the present invention.
While embodiments of this disclosure have been depicted and described and are defined by reference to example embodiments of the disclosure, such references do not imply a limitation on the disclosure, and no such limitation is to be inferred. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those skilled in the pertinent art and having the benefit of this disclosure. The depicted and described embodiments of this disclosure are examples only, and not exhaustive of the scope of the disclosure.

Detailed Description

Illustrative embodiments of the present invention are described in detail herein. In the interest of clarity, not all features of an actual implementation may be described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions may be made to achieve the specific implementation goals, which may vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of the present disclosure.

The terms “couple” or “couples,” as used herein are intended to mean either an indirect or a direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect electrical or mechanical connection via other devices and connections. The term “upstream” as used herein means along a flow path towards the source of the flow, and the term “downstream” as used herein means along a flow path away from the source of the flow. The term “uphole” as used herein means along the drillstring or the hole from the distal end towards the surface, and “downhole” as used herein means along the drillstring or the hole from the surface towards the distal end.

It will be understood that the term “oil well drilling equipment” or “oil well drilling system” is not intended to limit the use of the equipment and processes described with those terms to drilling an oil well. The terms also encompass drilling natural gas wells or hydrocarbon wells in general. Further, such wells can be used for production, monitoring, or injection in relation to the recovery of hydrocarbons or other materials from the subsurface. This could also include geothermal wells intended to provide a source of heat energy instead of hydrocarbons.

The present disclosure generally relates to subterranean operations. More particularly, the present disclosure relates to improved darts for use in subterranean wells.

Referring now to FIG. 1, a composite dart in accordance with an exemplary embodiment of the present disclosure is denoted generally with reference numeral 100. The composite dart 100 includes a foam portion 102 coupled to a rubber portion 104. At the tip of the composite dart 100 is a dart nose 106.

Although the exemplary composite dart 100 of FIG. 1 includes a foam portion 102 coupled to a first distal end of a rubber portion 104 and a dart nose 106 coupled to a second distal end of the rubber portion 104, the present disclosure is not limited to this particular arrangement. Accordingly, in another embodiment (not shown) the foam portion 102 may be positioned between the rubber portion 104 and the dart nose 106 instead. Specifically, the rubber portion 104 may be coupled to a first distal end of the foam portion 102 with the dart nose 106 coupled to the second distal end of the foam portion 102. Accordingly, the foam portion 102 may be located downstream or upstream from the rubber portion 104.

The foam portion 102 and the rubber portion 104 may be coupled to one another by any suitable means known to those of ordinary skill in the art. For instance, the foam portion 102 and the rubber portion 104 may be detachably or non-detachably coupled to each other. Specifically, in certain embodiments the foam portion 102 and the rubber portion 104 may be non-detachably coupled to each other by welding them together. In other embodiments, the foam portion 102 and the rubber portion 104 may be detachably bolted to each other or may be coupled to each other by fasteners such as, for example, screws. In yet another embodiment a threaded engagement may be used to couple the foam portion 102 and the rubber portion 104 in a detachable manner. In embodiments where the foam portion 102 and the rubber portion 104 are detachably coupled to one another, each component of the composite dart 100 may be replaced independent of the other. Accordingly, the replacement costs associated with using the composite dart 100 may be reduced because the operator may be able to only replace one of the foam portion 102 and the rubber portion 104 without having to dispose of the whole composite dart 100.

The foam portion 102 of the composite dart is not limited to any specific shape or geometry. Specifically, in one embodiment, the foam portion 102 may include a cylindrical portion and a conical portion as shown in FIG. 1. However, the foam portion may have any suitable geometry depending on the desired performance characteristics and job requirements. For instance, the foam portion 102 may be conical, cylindrical, elliptical, or a combination thereof. Moreover, the foam portion may be made from any suitable materials, including, but not limited to, a gel material.

The foam portion 102 may be any foamy material, such as a polymer, including, but not limited to, open-cell foams having natural rubber, nitrile rubber, styrene butadiene rubber, polyurethane, or any other foamy material. Any open-cell foam having a sufficient density, firmness, and resilience may be suitable for the desired application, depending on the compression and strength requirements of the given application.

In one embodiment, the rubber portion 104 may comprise a plurality of wiper cups. Although three wiper cups are shown in FIG. 1, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the present disclosure is not limited to any specific number of wiper cups. In fact, instead of using wiper cups, the rubber portion 104 may be polyurethane. As would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the rubber portion 104 may have any suitable geometry depending on the desired performance characteristics and job requirements. For instance, the rubber portion 104 may be conical, cylindrical, elliptical, or a combination thereof.

The rubber portion 104 may be made of any suitable material. In one embodiment, the rubber portion 104 may be made of hydrogenated nitrile or regular nitrile. In certain embodiments, the materials used for making the foam portion 102 and the rubber portion 104 may be selected to balance the ability of the components to conform to restrictions in their path against their ability to resist wear and tear.
The foam portion 102 and the rubber portion 104 of the composite dart 100 may be sized to properly engage the inner wall of the largest diameter casing through which the composite dart 100 will pass. For example, foam portion 102 may wipe clean the inner wall of a drill pipe as composite dart 100 travels the length of the drill pipe, which length may extend the entire length of the well bore. The foam portion 102 may also readily compress to pass through relatively small diameter restrictions without requiring excessive differential pressure to push the composite dart 100 to a desired location. For instance, the composite dart 100 may be used to wipe clean the inner wall of a drill pipe having an inner diameter that varies along its length. The foam portion 102 may have a substantially cylindrical shape with a tapered leading edge and/or trailing edge, or it may have a constant cross section. Alternatively, foam portion 102 may be reticulated, may have one or more ribs or fins or may have an otherwise varied cross section. When ribs or fins are present, gaps created in foam portion 102 may be at least partially filled with a different material, such as a filtering material or a foam with a different hardness. Generally, the outer diameter or other radial dimension of foam portion 102 and/or the rubber portion may exceed the corresponding dimension of the dart nose 106.

The composite dart 100 may thus conform to varying inside diameters and restrictions, allowing the use of specific tools which require restrictive orifices. Additionally, the composite dart 100 may adapt to more casing string sizes, resulting in fewer specific assembly configurations.

Accordingly, the composite dart 100 disclosed herein allows the foam portion 102 and the rubber portion 104 to operate in tandem, with each compensating for the drawbacks of the other. Specifically, the foam portion 102 may wipe the casing more effectively than the rubber portion 104. For instance, the foam portion 102 may be better suited for cleaning restrictions. At the same time, because the foam portion 102 is coupled to the rubber portion 104, there will be no easy landing. Specifically, the rubber portion 104 will engage the inner surface of the casing. As a result, the composite dart 100 remains in position and will not free fall through the casing even if the foam portion 102 has been compressed and has not expanded to its original size.

As the composite dart 100 moves downhole through the casing, it may effectively wipe and displace fluids in casings of different diameters including large diameter work strings. The composite dart 100 may then compress radially as it passes through one or more severe restrictions (such as internal upset tool joints), while continuing to wipe and displace fluids. Once the composite dart 100 emerges from such restrictions, the rubber portion 104 prevents an early landing of the composite dart 100 by engaging the casing, pipe wall or well bore walls before the foam portion 102 expands to its original shape.

In one embodiment, foam portion 102 may have at least two different compositions. For example, as illustrated in FIGS. 2-3, foam portion 102 may include a core of foam 50 that may be attached to the dart nose 106 or the rubber portion 104 (shown in FIG. 1). Core 50 may be surrounded by outer portion 60 of foam portion 102. Core 50 may be formed such that portions of core 50 have a diameter approximately equal to the diameter of outer portion 60, while other portions of core 50 have a smaller diameter than the diameter of outer portion 60 (shown in FIG. 2). Alternatively, core 50 may have a uniform diameter that is smaller than the diameter of outer portion 60 (shown in FIG. 3). In this embodiment, foam portion 102 may be sized to achieve adequate cleanup and displacement in larger of casing and liner above a severe restriction and core 50 may be sized to achieve adequate cleanup and displacement in casing and liner below restriction 90 (shown in FIG. 4B). In certain exemplary embodiments, the core 50 may have a hardness of about 90 IFD and outer portion 60 may have a hardness of about 50 IFD.

The composite dart 100 may have a dart nose 106 to sealingly engage a plug. Dart nose 106 may have a diameter or other radial dimension that is smaller than the corresponding diameter or radial dimension of the foam portion 102 and the rubber portion 104. In one embodiment, the dart nose 106 may be a separate component coupled to a leading end of the rubber portion 104 as shown in FIG. 1. In another embodiment, the foam portion 102 may be placed between the rubber portion 104 and the dart nose 106 with the dart nose 106 coupled to the foam portion 102 instead. In certain embodiments, the inner bore of dart nose 106 may be threaded to engage the corresponding foam portion 102 or rubber portion 104 to which it must attach, allowing the use of other shaped nose pieces in accordance with the desired shape for the plug with which the composite dart 100 will interact. For example, in one embodiment the dart nose 106 may be tapered to facilitate entry of the composite dart 100 into the plug.

The dart nose 106 may be constructed from any material suitable for use in the subterranean environment in which composite dart 100 may be placed. For example, dart nose 106 may be constructed from a drillable material such as plastics, phenolics, composite materials, high strength thermoplastics, aluminum, glass, and/or brass. Referring to FIGS. 4A-4C, the composite dart 100 may progress down a casing string (FIG. 4A) while maintaining contact with the casing string through various restrictions. As the composite dart 100 is compressed radially (FIG. 4B) to pass through the restriction 90, the foam portion 102 is easily compressed and cleans the restriction 90. As the composite dart 100 exits the restriction 90 (FIG. 4C), the rubber portion 104 which is not as compressible as the foam portion 102 remains in contact with the work string and prevents a free fall of the composite dart 100. Specifically, although the foam portion 102 may be deformed upon exiting the restriction 90 and may not be in contact with the walls of the work string, the rubber portion 104 remains in contact with the work string and holds the composite dart 100 in place.

The composite dart 100 may then be moved through the tubular string until it reaches restriction 90. This movement may be caused via pumping down the tubular string and/or differential pressure. The composite dart 100 may be allowed to compress radially as it moves through restriction 90, and allowed to expand to maintain contact with the tubular string after passing through restriction 90. The composite dart 100 may continue through tubular string, causing it to travel through the drill pipe until it contacts the plug. Once the dart nose 106 has contacted its mating seat profile within the plug, a differential pressure may be applied across the sealing diameter of the dart nose 106 and its mating seat profile so as to "activate" the plug, or cause the plug to be deployed so as to carry out an intended function within the casing. For example, a plug may be activated to cause it to detach from a work string and travel through the casing in order to serve as a spacer between different fluids that are desirably segregated.
Thus, the composite dart 100 may be capable of cleaning and displacing fluids in a large-size casing string and/or liner, passing through one or more severe restrictions, and cleaning and displacing fluids in a smaller size pipe and/or tool before landing on a seat. Although the present disclosure describes the operation of the composite dart 100 in conjunction with a casing string, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the composite dart 100 may also be introduced into a drill pipe or other tubular strings within the well bore at the surface.

Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

What is claimed is:

1. A dart comprising:
   a) a foam portion;
   b) a rubber portion coupled to the foam portion; and
   c) a dart nose coupled to at least one of the foam portion and the rubber portion;
   wherein the foam portion and the rubber portion are configured to interface with an inner surface of at least one of a well bore wall, a pipe, and a casing string.

2. The dart of claim 1, wherein the foam portion is made from a gel material.

3. The dart of claim 1, wherein the rubber portion is made from polyurethane.

4. The dart of claim 1, wherein the foam portion and the rubber portion are detachably coupled.

5. The dart of claim 4, wherein at least one of a threaded engagement, a bolt, and a screw detachably couples the foam portion to the rubber portion.

6. The dart of claim 1, wherein the foam portion and the rubber portion are non-detachably coupled.

7. The dart of claim 1, wherein the foam portion comprises at least one of a conical portion, a cylindrical portion, an elliptical portion and a combination thereof.

8. The dart of claim 1, wherein the rubber portion comprises at least one of a conical portion, a cylindrical portion, an elliptical portion and a combination thereof.

9. A method of cleaning a restriction in a casing comprising:
   a) placing a dart in the restriction;
   b) wherein the dart comprises a foam portion coupled to a rubber portion;
   c) passing the dart through the restriction;
   d) wherein at least one of the foam portion and the rubber portion cleans an inner surface of the restriction; and
   e) directing the dart out of the restriction to a wider portion of the casing;
   f) wherein a diameter of the wider portion of the casing exceeds a diameter of the restriction; and
   g) wherein the rubber portion interfaces with an inner surface of the wider portion of the casing before the foam portion interfaces with an inner surface of the wider portion of the casing.

10. The method of claim 9, wherein the foam portion is made from a gel material.

11. The method of claim 9, wherein the rubber portion is made from polyurethane.

12. The method of claim 9, wherein the foam portion and the rubber portion are detachably coupled.

13. The method of claim 12, wherein at least one of a threaded engagement, a bolt, and a screw detachably couples the foam portion to the rubber portion.

14. The method of claim 9, wherein the foam portion and the rubber portion are non-detachably coupled.

15. The dart of claim 9, wherein the foam portion comprises at least one of a conical portion, a cylindrical portion, an elliptical portion and a combination thereof.

16. The dart of claim 9, wherein the rubber portion comprises at least one of a conical portion, a cylindrical portion, an elliptical portion and a combination thereof.

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