Title: HIGH-STRENGTH BLOWOUT PREVENTER SHEARING RAM AND CONNECTING ROD

Abstract: A blowout preventer includes a housing, comprising a longitudinal bore extending therethrough and a cavity intersecting the bore, and a pair of opposing shear rams configured to shear a tubular located in the longitudinal bore. The opposing shear rams can be moved radially into and out of the longitudinal bore by connecting rods coupled to the shear rams. The connecting rods may be coupled to the shear rams via intermediate connecting assemblies which may include a split-flange connector comprising multiple sections. The shear rams and/or the connecting rods may be constructed of a high-strength heat treatable, low alloy steel, such as AISI 4340 steel. The shear rams are constructed of a single material having a higher hardness than that of the tubular product.
High-Strength Blowout Preventer Shearing Ram and Connecting Rod

Background

[0001] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the presently described embodiments. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present embodiments. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0002] In order to meet consumer and industrial demand for natural resources, companies often invest significant amounts of time and money in finding and extracting oil, natural gas, and other subterranean resources from the earth. Particularly, once a desired subterranean resource such as oil or natural gas is discovered, drilling and production systems are often employed to access and extract the resource. These systems may be located onshore or offshore depending on the location of a desired resource. Further, such systems generally include a wellhead assembly through which the resource is extracted. These wellhead assemblies may include a wide variety of components, such as various casings, valves, fluid conduits, and the like, that control drilling or extraction operations.

[0003] More particularly, wellhead assemblies often include a blowout preventer to control pressure at the top of a well and prevent flow of formation fluids through the blowout preventer. A shear ram blowout preventer achieves pressure control through the operation of hydraulically operated rams capable of shearing a tubular contained within a main bore of the blowout preventer (e.g., drill pipe, a liner, or a casing string). The rams are grouped in opposing pairs and are forced together as a result of the hydraulic operation. Often, the rams are driven into and out of a main bore of a blowout preventer by operating pistons coupled to the ram blocks by connecting rods.

[0004] An object of the present disclosure is to provide an improved shear ram for use in a blowout preventer which is able to shear high-strength drilling tubulars including tool joints, drill collars, and hard-banded pipe and casing. Another object of the present disclosure is to provide a shear ram which is able to be reused by way of simple machining after encountering mechanical damage during shearing operations. Yet another object of the present disclosure is to provide an improved shear ram actuation assembly including an improved connecting rod which is able to provide for shearing of high-strength drilling tubulars including tool joints, drill collars, and hard-banded pipe and casing.
pects of some embodiments disclosed herein are set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of certain forms the invention might take and that these aspects are not intended to limit the scope of the invention. Indeed, the invention may encompass a variety of aspects that may not be set forth below.

[0006] Embodiments of the present disclosure generally relate to high-strength shear rams and actuation assemblies including connecting rods for moving same. In some embodiments, a blowout preventer includes a housing, comprising a longitudinal bore extending therethrough and a cavity intersecting the bore, and pair of opposing shear rams configured to shear a tubular located in the longitudinal bore. The opposing shear rams can be moved radially into and out of the longitudinal bore by connecting rods coupled to the shear rams. The connecting rods may be coupled to the shear rams via intermediate connecting assemblies which may include a split-flange connector comprising multiple sections. The connecting rods may be moved radially toward or away from the longitudinal bore by hydraulically actuated pistons coupled to the connecting rods.

[0007] In some embodiments, the shear rams and/or the connecting rods may be constructed of a high-strength heat treatable, low alloy steel, such as AISI 4340 steel. That is, the shear rams are constructed of a single material having a higher hardness than that of the tubular product to be sheared, including tool joints. The shear rams are configured to shear such a tubular product without regard to the tubular product's diameter, wall thickness, or any hard-banding which may be in the cutting plane of the ram.

[0008] Various refinements of the features noted above may exist in relation to various aspects of the present embodiments. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of some embodiments without limitation to the claimed subject matter.

**Brief Description of the Drawings**

[0009] For a more detailed description of the embodiments, reference will now be made to the following accompanying drawings:

[0010] FIG. 1 shows a schematic view of an embodiment of a subsea hydrocarbon drilling system in accordance with various embodiments;
A cross-sectional isometric view of a blowout preventer in accordance with various embodiments;

FIG. 3A shows a ram block in accordance with various embodiments;

FIG. 3B shows a ram block in accordance with various embodiments; and

FIG. 4 shows an isometric view of an actuation assembly in accordance with various embodiments.

Detailed Description of the Disclosed Embodiments

The following discussion is directed to various embodiments of the present disclosure. The drawing figures are not necessarily to scale. Certain features of the embodiments may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but are the same structure or function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to..." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. In addition, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a
ns a distance measured perpendicular to the central axis. The use of "top," "bottom," "above," "below," and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0018] Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present disclosure. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0019] Turning now to FIG. 1, a subsea blowout preventer stack assembly 100 is assembled onto a wellhead assembly 102 on the sea floor 104. The blowout preventer stack assembly 100 is connected in line between the wellhead assembly 102 and a floating rig 106 through a subsea riser 108. The blowout preventer stack assembly 100 provides pressure control of drilling/formation fluid in the wellbore 110 should a sudden pressure surge escape the formation into the wellbore 110. The blowout preventer stack assembly 100 thus prevents damage to the floating rig 106 and the subsea riser 108 from fluid pressure exiting the seabed wellhead.

[0020] The blowout preventer stack assembly 100 includes a lower marine riser package 112 that connects the riser 108 to a blowout preventer stack package 114. The blowout preventer stack package 114 includes a frame 116, blowout preventers 118, and accumulators 120 that may be used to provide back up hydraulic fluid pressure for actuating the blowout preventers 118. In some embodiments, the blowout preventers 118 are shear ram-type blowout preventers, such as those shown in FIGS. 2-4. The blowout preventer stack package 114 may include multiple types of blowout preventers, each designed to effectuate a different result. For example, the blowout preventer stack package 114 may include blind rams and pipe rams to seal the bore and around the drill pipe, respectively. In addition, the blowout preventer stack package 114 may include an annular blowout preventer and additional shear rams.

[0021] Turning now to FIG. 2, a cross-sectional, isometric view of a blowout preventer 200 is shown. Blowout preventer 200 may be included in a blowout preventer stack assembly, such as blowout preventers 118 in blowout preventer stack assembly 100 illustrated in FIG. 1. The blowout preventer 200 includes a pair of opposing rams 202, 204. The rams 202, 204 are urged together in response to hydraulic actuation. When urged together, in some
202, 204 are designed to shear an object 206 (e.g., drilling tubular, tool joint, drill collar, production tubular, hard-banded pipe, casing tubular, etc.) that is in the wellbore between the rams 202, 204. Particular features of the rams 202, 204 are discussed in further detail below.

[0022] The blowout preventer further includes a partially hollow main body 208 and a longitudinal bore 210 that allows fluids (e.g., drilling fluids, completion fluids, treating fluids, produced fluids, etc.) or devices (e.g., drill string, casing string, production string, etc.) to pass through the blowout preventer 200. The depicted blowout preventer 200 can be mounted on a wellhead or another component by way of a lower connection flange 212. Additional equipment (e.g., subsea connector, lower marine riser package, etc.) may be installed on the blowout preventer 200 via top end connection 214 of the blowout preventer 200.

[0023] Actuation/bonnet assemblies 216 secured to the main body 208 include various components that facilitate control of rams 202, 204 disposed in ram cavities 222 of the blowout preventer 200. Bonnet assemblies 216 include hydraulically actutable pistons 218 coupled to ram shafts 220. In operation, a force (e.g., from hydraulic pressure) may be applied to the pistons 218 to drive the rams 202, 204, via the ram shafts 220, into the bore 210 of the blowout preventer 200. The rams 202, 204 are shear rams that are driven together to shear the object 206 and inhibit flow through the blowout preventer 200. Further, the rams 202, 204 can have any desired size and shape, which may vary depending on the intended application.

[0024] Turning now to FIGS. 3A and 3B, isometric views of opposing shear rams 302, 304 are shown, by way of example. Shear rams 302, 304 may be used in a blowout preventer assembly, such as blowout preventer 200 illustrated in FIG. 2. Shear ram 302 includes a generally V-shaped upper arm 306 that includes an integral, angled cutting face 308. Shear ram 302 further includes a protrusion 310 extending from either side of the shear ram 302. As discussed above, shear ram 302 may be coupled to an actuation assembly including a connecting rod. When actuated, shear ram 302 can be moved into and out of a bore, such as longitudinal bore 210 illustrated in FIG. 2.

[0025] Shear ram 304 includes a generally V-shaped lower arm 312 that include an integral, angled cutting face 314. Shear ram 304 further includes a slot 316 extending into either side of the shear ram 304. The slot 316 is configured to receive a corresponding protrusion located on an opposing shear ram, such as protrusion 310 located on shear ram 302. As discussed above, shear ram 304 may be coupled to an actuation assembly including a...
hen actuated, shear ram 304 can be moved into and out of a bore, such as longitudinal bore 210 illustrated in FIG. 2. Further, the rams 302, 304 are designed such that the rams 302, 304 interlock when urged together during shearing operations. The interlocking profile prevents the rams 302, 304 from separating during high shearing loads.

[0026] When shear rams 302 and 304 are urged together in response to hydraulic actuation, the shear rams 302, 304 are designed to shear an object, such as the object 206 illustrated in FIG. 2. Specifically, upon contact with the object, shear rams 302 and 304 penetrate the object, and separate the object into upper and lower portions. Because of the V-shaped geometry of each shear ram 302, 304, the rams are capable of centralizing the object to be sheared in the event shear ram 302 and/or 304 is off-center during shearing operations.

[0027] Shear rams 302, 304 each include a throat radius on their respective cutting faces 308, 314 which allows for larger objects to bear against a relatively small section of the respective cutting faces 308, 314, thereby developing a high bearing stress in the object resulting in a more reliable shear. Further, when urged together, slot 316 of shear ram 304 receives protrusion 310 of shear ram 302 in a tongue-and-groove type interface. This interface strengthens the engagement between shear rams 302 and 304 and prevents undesired separation during the shearing process.

[0028] As discussed above, shear rams 302, 304 are each integrally formed rams constructed of one type of material, i.e., the rams do not include any inserts or sealing element. In such an embodiment, sealing of the bore can be effectuated by other rams in the stack, allowing the high-strength shears to focus on shearing. In some embodiments, shear rams 302, 304 can be constructed of a high-strength heat treatable, low alloy steel, such as AISI 4340 steel. AISI 4340 steel is a nickel-chromium-molybdenum alloy steel. The shear rams 302, 304 are formed of AISI 4340 steel such that the hardness is maintained relatively constant from the surface of the rams into the core of the rams, relative to existing shear rams. That is, existing shear rams typically have hardness properties that vary greatly from the surface of the ram through the core of the ram. The present disclosure teaches a shear ram with a more consistent hardness property from the surface of the ram to the core of the ram, i.e., less hardness variability.

[0029] Generally, the shear rams 302, 304 can be formed of any material with a Brinell hardness greater than about 321. As a result, shear rams 302, 304 are harder than existing shear rams and can shear tubulars that existing rams cannot shear, or have difficulty shearing, such as tool joints, drill collars, and hard-banded pipe. Because the shear rams 302, 304 are formed of one integral piece, as opposed to a ram including cutting inserts and
rams are harder and stronger throughout the body of the rams 302, 304, *i.e.*, from the surface of the rams 302, 304 to the cores of the rams 302, 304. Further, because the rams 302, 304 consist of only one structure, there are no components that can break off during shearing operations. Moreover, the cutting face of the rams 302, 304 can be reclaimed after use by repair or remanufacture machining as a result of the hardness of the material of construction. For example, the hardness and design of the exemplary shear rams can effect shearing without requiring as tightly controlled tolerances between the two rams. Accordingly, the useful life of the shear rams 302, 304 can be extended.

[0030] Turning now to FIG. 4, an isometric view of a shear ram 402 and connector rod 404 of an actuation assembly is show, by way of example. As discussed above, blowout preventers, such as blowout preventer 200 illustrated in FIG. 2, include actuation assemblies for moving shear rams into and out of a longitudinal bore of the blowout preventer. In FIG. 4, shear ram 402 is coupled to connector rod 404 by way of a connecting assembly 406 inserted into a recess 416 in the shear ram 402. Connecting assembly 406 is shown as being a substantially rectangular flange comprising multiple sections, which will be discussed in greater details below. However, other geometries are envisioned.

[0031] Connector rod 404 is inserted into shear ram 402 through a circular cavity 408 formed in the rear portion of shear ram 402. In the illustrated embodiment, the cavity 408 is vertically and horizontally centrally positioned in the rear portion of shear ram 402. However, the cavity 408 may be located at other positions in the rear of shear ram 402. The connector rod 404 is also inserted through connecting assembly 406 which is composed of multiple sections 410 and 412. Sections 410 and 412 form a substantially circular aperture through which the connector rod 404 can be inserted. The connector rod 404 includes a groove 414 formed on the outer surface of connector rod 404 near the end of the connector rod 404 inserted into cavity 408. Groove 414 is shown located about the entire circumference of the outer surface of connector rod 404. However, groove 414 could be located about only a portion of the circumference of the outer surface of connector rod 404. Groove 414 is formed to receive sections 410 and 412 of the connecting assembly 406. The groove may have a profile—*e.g.*, a series of valleys and ridges—that mate with a complementary profile on the sections 410 and 412, to improve the engagement therebetween.

[0032] When connector rod 404 is inserted into cavity 408, sections 410 and 412 of the connecting assembly 406 are recessed into groove 414. In this configuration, the connector rod 404 and shear ram 402 are prevented from moving with respect to one another. That is,
Dnector rod 404 results in movement of the shear ram 402. In order to firmly engage the connecting apparatus 406 to the connector rod 404, a fastener (e.g., a pin, a bolts, a stud, etc.) may be inserted into the connecting apparatus 406, thereby engaging sections 410 and 412. By securing the connector rod 404 in this manner, the loads on the connector rod can be more evenly distributed, improving the shearing ability of the rams.

[0033] As discussed above, the present disclosure presents shear rams and connector rods for shearing any object within the cutting plane of the rams, namely drilling tubulars, tool joints, drilling collars, production tubulars, hard banded pipe segments, casing tubulars, and the like.

[0034] While specific embodiments have been shown and described, modifications can be made by one skilled in the art without departing from the spirit or teaching of this invention. The embodiments as described are exemplary only and are not limiting. Many variations and modifications are possible and are within the scope of the invention. For example, the disclosed interaction between the skeletal members and the ram arms is intended to apply to any support structure that is integrated into a packer to resist forces acting on cantilevered portions of a ram block. As another example, the coupling between the skeletal structure and the ram arms may take many different forms other than those mentioned above. Still further, it is not necessary that both of a set of ram blocks include the described skeletal structure. Accordingly, the scope of protection is not limited to the embodiments described, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.
What is Claimed is:

1. A shear ram comprising:
   a body; and
   a protrusion extending from the body configured to couple the shear ram to a corresponding shear ram to oppose vertical separation of the rams; and
   wherein the body consists of a material having a Brinell hardness greater than about 321.

2. The shear ram of claim 1, wherein the corresponding shear ram includes a slot configured to receive the protrusion.

3. The shear ram of claim 1, further comprising a recess in the body configured to receive a connecting apparatus configured to couple the body to a connector rod.

4. The shear ram of claim 3, wherein the connector rod comprises a groove on an outer diameter of the connector rod configured to receive the connecting apparatus.

5. The shear ram of claim 3, wherein the connecting apparatus comprises multiple sections.

6. The shear ram of claim 3, further comprising a fastener to secure the connecting apparatus to the connector rod.

7. The shear ram of claim 3, wherein the shear ram and connector rod are movable together.

8. The shear ram of claim 1, wherein the body is configured to shear at any orientation of an object.

9. The shear ram of claim 8, wherein the object is one of a tool joint, a drill collar, a production tubular, a hard banded tubular, and a casing tubular.

10. The shear ram of claim 1, wherein the body is V-shaped.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
E21B 33/03(2006.01)i, E21B 33/06(2006.01)i, E21B 33/064(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B 33/03; E21B 29/08; E21B 33/06; E21B 19/22; E21B 19/00; E21B 29/00; E21B 33/064

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: blowout prevent, shear ram, body, protrusion, slot, Brinell hardness, connector rod, and connecting apparatus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 4313496 A (CHILDS et al.) 02 February 1982 See column 2, line 16 - column 3, line 53 and figures 1-5.</td>
<td>1-10</td>
</tr>
<tr>
<td>Y</td>
<td>US 4923005 A (LAKY et al.) 08 May 1990 See column 2, lines 24-49 and figures 10-11.</td>
<td>3-7</td>
</tr>
<tr>
<td>A</td>
<td>US 4540046 A (GRANGER et al.) 10 September 1985 See column 2, lines 38-53 and figure 3.</td>
<td>1-10</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 25 June 2016 (25.06.2016)
Date of mailing of the international search report 27 June 2016 (27.06.2016)

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongna-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
PARK, Tae Wook
Telephone No. +82-42-481-3405

Form PCT/ISA/210 (second sheet) (January 2015)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 4313496 A</td>
<td>02/02/1982</td>
<td>CA 1140454 A</td>
<td>01/02/1983</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 56-167092 A</td>
<td>22/12/1981</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 64-009440 B2</td>
<td>17/02/1989</td>
</tr>
<tr>
<td>US 6173770 Bl</td>
<td>16/01/2001</td>
<td>AU 1999-29939 Al</td>
<td>18/10/1999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>¥0 99-49179 Al</td>
<td>30/09/1999</td>
</tr>
<tr>
<td>US 4923005 A</td>
<td>08/05/1990</td>
<td>GB 2253227 A</td>
<td>02/09/1992</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 4986360 A</td>
<td>22/01/1991</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2587916 Al</td>
<td>01/06/2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2587916 C</td>
<td>28/04/2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1825097 A4</td>
<td>24/10/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MX 2007006317 A</td>
<td>23/11/2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO 20072627 A</td>
<td>29/06/2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WD 2006-058244 A2</td>
<td>01/06/2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>¥0 2006-058244 A3</td>
<td>22/02/2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 60-085189 A</td>
<td>14/05/1985</td>
</tr>
</tbody>
</table>