Abstract:

Title: 4-ROUND THREAD FORM

The thread form disclosed herein includes a load flank angle, a stab flank angle, and a crest angle. The load flank angle is greater than the stab flank angle. The crest angle is greater than the load flank angle and the stab flank angle. The thread form is designed to improve the strength and durability of the pipe.

FIG. 1

4-ROUND THREAD FORM

Experimental thread form including a load flank angle, a stab flank angle, and a crest angle. The load flank angle is greater than the stab flank angle, and the crest angle is greater than both the load and stab flank angles.

(54) Title: 4-ROUND THREAD FORM


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4-Round Thread Form

The subject matter disclosed is generally related to piping thread forms, in particular 4-round thread forms (i.e., four thread per inch pipe forms).

Common piping used in oil pipelines generally feature eight (8) thread per inch (TPI) thread forms, also known as 8-round. This thread form is capable of withstanding high pressures and the associated tensile loads as required by American Petroleum Institute (API) standards. However, eight thread per inch thread forms are prone to cross-threading during installation, especially in larger diameter piping.

Additionally, while hundreds of thread forms may exist, many thread forms appropriate for metal piping, such as a buttress thread, cannot be machined into composite pipes due to issues with chipping and cracking. Issues with chipping and cracking are especially present with the sharp angles of the buttress thread. Similarly, premium threads, a class of high-performance thread types commonly used in modern oilwell and gaswell completions, are available in a number of configurations and are typically designed to provide superior hydraulic sealing, improved tensile capacity and ease of make-up. However, due to the machining issues with composite piping, premium threads also cannot be fully implemented into composite piping.
Accordingly, there is need for a thread form that is less prone to cross-threading during installation and capable of being machined into composite piping, yet still capable of withstanding high pressures and tensile loads.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the disclosure can be better understood with reference to the following drawings, wherein:

FIG. 1 shows a schematic view of a thread form of the present subject matter;
FIG. 2 shows burst test set up for hydrostatic testing;
FIG. 3 shows a spool assembly for tensile testing;
FIGS. 4A-B show a tensile pull test assembly;
FIGS. 5A-D show tensile test specimen; and
FIGS. 6A-B show a make and break test specimen.

DETAIL DESCRIPTION

Reference is now made in detail to the description of non-limiting embodiments as illustrated in the drawings. While the embodiments described may use specific materials or configurations, there is no intent to limit the subject matter to the embodiment or embodiments disclosed herein. Accordingly, various modifications to the embodiments presented may be readily apparent to those skilled in the art, and the generic principles described herein can be applied to other non-limiting embodiments without departing from the spirit or scope of the claimed subject matter. As such, this detailed description of various alternative embodiments should not be construed to limit the scope or breadth of the present apparatus, system and method as set forth in the claims.
FIG. 1 shows an exemplary embodiment of a 4-round thread form for piping, comprising a load flank, a stab flank, a crest, and a root. The load flank is sloped at a load flank angle, which is measured from a line that is perpendicular to an axis of the pipe. The stab flank is sloped at a stab flank angle, which is also measured from the line perpendicular from the axis of the pipe, but in the opposite direction. In the exemplary embodiment shown in FIG. 1, the load flank angle is 62 degrees and the stab flank angle is 25 degrees, however the stab flank angle can be any angle between 15 and 25 degrees. Accordingly, in the exemplary embodiment shown, an angle between the load flank and the stab flank can range from 77 to 87 degrees. Additionally, the thread form shown in FIG. 1 includes a ¾” taper per foot (TPF).

The embodiment shown in FIG. 1 is exemplary and intended to show the 4-round thread form. Of course, in application, the thread form is applied to both the external (male) threaded portion and internal (female) threaded portions, which would be configured to form a complete threaded connection between two pipes. Additionally, the exemplary 4-round thread form can be implemented on both large and small diameter piping.

Tensile test results of 4-round thread form samples, in accordance with the 4-round thread form of FIG. 1, show that the 4-round thread form can withstand more than twice the tensile load of the conventional 8-round thread form. The strength of a thread form is measured by determining what tensile force is necessary to shear the engaged thread on a per-square-inch of engaged area basis. Conventional 8-round thread forms typically fail at around 1,500 psi during tensile tests. If the test sample is under pressure and the tensile load is a result of end thrust, then the result improves to about 2,000 psi prior to shearing. The first 4-
round thread form sample failed at 3,800 psi in a straight pull test without pressure. In two additional tests, the 4-round thread form failed at 3,700 and 3,900 psi.

Additionally, pressure testing of two samples of the 4-round thread also showed excellent results. The first 4-round thread form sample was left at 2,500 psi for a night and a day, and no leaks were present. The second 4-round thread sample form was burst tested, and failed the test head at 3700 psi. A more complete description of the test setup and test results is presented below.

Hydrostatic Test

Shown in Fig. 2 is a burst test set up, for hydrostatic pressure tests of specimens for 6-5/8" Yellow Box assembly using the 4-round thread form described above with respect to FIG. 1 and with 4 TPI (threads per inch) 3/4" TPF (taper per foot). For convenience, (60/25) indicates a 4-round thread form having a 60 (62) degree stab flank angle and a 25 degree load flank angle.

The test assembly as shown in FIG. 2 includes the following: a steel end cap (6.5" L4 long 60/25 box end), a nipple (6.5" L4 60/25 pin end x 4.0" L4 60/25 pin end), a coupler (4.0" L4 60/25 box end x 4.0" L4 60/25 box end), a nipple (4.0" L4 60/25 pin end x 6.5" L4 60/25 pin end), and steel end cap (6.5" L4 60/25 box end).

Assembly and testing of the 4-round thread form specimens was conducted as follows. The threads on both the box (internal threads / female) and pin (external threads / male) were cleaned of any foreign matter using a clean cloth and a soft brush. Teflon tape was applied on the pin threads. The Teflon tape was rolled tight around the pin end in a clockwise direction starting from the vanish point of the larger body end of the 4-round thread form, proceeding to the last thread on the pin, and returning to the vanish point. During application of the Teflon
tape, it was attempted to fully cover each thread of the 4-round thread form on each revolution. Thread compound type TF-15 (manufacturer: Jet-Lube Inc.) was then applied to the threads of the box (internal threads) and pin (external threads). The threaded joint was then assembled by hand until "hand-tight". A power tong was then used to complete the assembly using an approximate torque value of 2,700 lb-ft.

The hydrostatic test was conducted to measure the maximum hydrostatic pressure for the 4-round thread form. Initially, the test sample was pressured from 0 to 2000 psi without stopping. The test sample was then pressured, in 500 psi increments in 5 to 10 minute intervals, up to a pressure of 4000 psi. The pressure was then reduced in 250 psi increments in 5 minute intervals. This procedure was repeated until failure. All failures were due to thread leaks. The results of the hydrostatic tests are shown Table-1

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Thread Compound</th>
<th>Coupling OD (inches)/L4</th>
<th>Test Results</th>
<th>Type of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tape &amp; Black</td>
<td>8.310/4</td>
<td>Burst</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Tape &amp; Black</td>
<td>8.310/4</td>
<td>Burst</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Tape &amp; Black</td>
<td>10.050/4.5</td>
<td>Burst</td>
<td>10 / 5</td>
</tr>
<tr>
<td>4</td>
<td>Grey</td>
<td>10.050/4.5</td>
<td>Burst</td>
<td>10 / 5</td>
</tr>
<tr>
<td>5</td>
<td>5.425</td>
<td>10.050/4.5</td>
<td>Burst</td>
<td>10 / 5</td>
</tr>
</tbody>
</table>

Table-1

Tensile Test
Shown in FIG. 3 a spool assembly for tensile testing of seven (7) specimens for 9-5/8" Yellow Box assembly using the 4-round thread form (60/25) and (60/15) with 4 TPI ¾" TPF. For convenience, (60/25) indicates a 4-round thread form having a stab flank angle of 60 degrees and a load flank angle of 25 degrees, (60/15) indicates a 4-round thread form having a stab flank angle of 60 degrees and a load flank angle of 15 degrees.

Assembly and testing of the 4-round thread form specimens was conducted as follows. The threads on both the pin (external threads / male) and the box ends (internal thread / female) were cleaned of any foreign matter using a clean cloth and a soft brush. Teflon tape was then applied on the pin threads. Tape was rolled tight around the pin end in a clockwise direction starting from the vanish point of the larger body end of the thread, proceeding to the last thread on the pin, and returning to the vanish point. During application of the Teflon tape, it was attempted to fully cover each thread of the 4-round thread form on each revolution. Then thread compound type TF-15 (manufacturer: Jet-Lube Inc.) was applied on threads of box and pin.

The joint was then assembled by hand until "hand-tight". A power tong was then used to complete the assembly using an approximate torque value of 2,700 lb-ft. See FIGS. 4A-B. The tensile load test was executed to verify the tensile strength for the 4-round thread form. In the tensile load test, steel fixtures were used to pull the assembly shown in FIG. 2. A total of 6 samples were pulled for during tensile load testing. The assembly mounted on the tensile tester is shown in FIGS. 4A-B.

Extensive experience with standard American Petroleum Institute (API) 8-round threaded connections verifies that the thread shear anticipated on a straight pull tensile test will be around 1,600 psi. In other words, each square inch of engaged thread will typically
withstand a shear load of around 1,600 psi. The shear force values indicated below in Table-2 indicate the ultimate shear strength per square inch of engaged thread of the 4-round thread form.

The initial test piece was assembled as shown in FIG. 3, including the following: a half coupling with 8 round thread, \( L_4 = 6.5'' \); a nipple threaded on one end with conventional 8-round thread form, \( L_4 = 6.5'' \), and on the other end threaded with 4-round thread form, \( L_4 = 5.5'' \); a coupler threaded both ends with 4-round thread form, \( L_4 = 5.5'' \); a nipple threaded on one end with 4-round thread form, \( L_4 = 5.5'' \), and the other end threaded with conventional 8-round thread form \( L_4 = 6.5'' \); and a half coupling with conventional 8-round thread form, \( L_4 = 6.5'' \). An electronic crane scale with a 300,000 lb capacity was used to measure the tensile force on each pull. A 15" hydraulic cylinder mounted in the test frame provided the tensile force for each pull.

The first pull, which is not recorded here, sheared the conventional 8-round thread form connection, despite it being one inch shorter in thread length. A second sample was prepared wherein \( L_4 \) on the 4-round thread form was reduced to 3.5". Again the conventional 8-round thread failed. Finally specimen 1, which is recorded below, was prepared with an \( L_4 \) of 2.5". The M dimension is 0.713, thus leaving an effective engaged thread length of 1.787". Six such samples, three of the 60/25 4-round thread form and three of the 60/15 4-round thread form were tested and recorded below.

<table>
<thead>
<tr>
<th>9-5/8&quot; RB sample</th>
<th>Thread type</th>
<th>Nominal ID (inches)</th>
<th>Tensile Load (lbs)</th>
<th>Effective thread Length (inches)</th>
<th>Shear force (psi)</th>
<th>Failure type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen # 1</td>
<td>60/25</td>
<td>7.840</td>
<td>204,000</td>
<td>1.787</td>
<td>3,849</td>
<td>Sheared off</td>
</tr>
<tr>
<td>Specimen # 2</td>
<td>60/25</td>
<td>7.840</td>
<td>204,000</td>
<td>1.787</td>
<td>3,849</td>
<td>Sheared off</td>
</tr>
<tr>
<td>Specimen # 3</td>
<td>60/25</td>
<td>7.840</td>
<td>199,200</td>
<td>1.787</td>
<td>3,758</td>
<td>Sheared off</td>
</tr>
<tr>
<td>Thread 60/25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,818</td>
<td></td>
</tr>
</tbody>
</table>
As can be seen by the results above in Table-2, the average value of shear strength for the 4-round thread form is 2 to 2.4 times that of the conventional 8-round thread form.

During testing, shear failure occurred at the fiberglass (Nipple) to fiberglass (Coupler) connection, see FIGS. 5A-D, however the sample body was not damaged in any of the six tests.

In order to establish the capacity of the 4-round thread form to be repetitively made up and broken out, an 8 inch nipple and coupling threaded with a 9-5/8” size thread was torqued up to 2,700 ft lbs and broken out 10 times consecutively. After the 10 such cycles the thread was inspected and found to have suffered no notable galling, cracking, or other damage whatsoever. See FIGS. 6A-B.

The disclosure provided herein fully describes the thread form in such clear and concise terms as to enable those skilled in the art to understand and practice the same, and the generic principles described herein can be applied to other embodiments without departing from the spirit or scope of this disclosure. Thus, it is to be understood that the description and drawings presented herein represent a presently preferred embodiment of the subject matter and are therefore representative of the subject matter which is broadly contemplated by the present disclosure.
CLAIMS

1. A thread form comprising:
   a predetermined number of threads per inch;
   a load flank having a load flank angle;
   a stab flank having a stab flank angle;
   a crest portion between the stab flank and the load flank; and
   a root portion between the load flank and the stab flank, wherein the load flank
   angle is approximately between 2.4 and 4.0 times the stab flank angle in the
   root portion.

2. The thread form of claim 1, wherein said predetermined number of threads per
   inch is less than a standard predetermined number of threads per inch.

3. The thread form according to claim 2, wherein said predetermined number of
   threads per inch is 4 threads per inch.

4. The thread form of claim 1, wherein said crest portion is configured to have a
   radius of 0.020 inches.

5. The thread form of claim 1, wherein said root portion is configured to have a
   radius of 0.017 inches.

6. The thread form of claim 1, wherein the load flank angle is between 60 degrees
   and 62 degrees.
7. The thread form of claim 1, wherein the stab flank angle is between 15 degrees and 25 degrees.

8. A composite pipe, comprising:
   a first threaded end comprising a four thread per inch thread form;
   the thread form comprising load flank having a load flank angle;
   a stab flank having a stab flank angle;
   a crest portion between the stab flank and the load flank; and
   a root portion between the load flank and the stab flank, wherein the load flank angle is approximately between 2.4 and 4.0 times the stab flank angle in the root portion.

9. The composite pipe of claim 8, wherein the load flank angle is between 60 degrees and 62 degrees.

10. The composite pipe of claim 8, wherein the stab flank angle is between 15 degrees and 25 degrees.

11. A threaded coupler, comprising: an internal 4-round thread form having a load flank having a load flank angle;
    a stab flank having a stab flank angle;
    a crest portion between the stab flank and the load flank; and
a root portion between the load flank and the stab flank, wherein the load flank angle is approximately between 2.4 and 4.0 times the stab flank angle in the root portion.

12. The threaded coupler of claim 11, wherein the load flank angle is between 60 degrees and 62 degrees.

13. The threaded coupler of claim 11, wherein the stab flank angle is between 15 degrees and 25 degrees.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/049154

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F16L 15/06 (2014.01)
CPC - F16L 15/06 (2014.10)

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)
IPC(8) - E21B 17/042; F16L 15/06 (2014.01)
CPC - E21B 17/042; F1BL 15/001, 15/06 (2014.10)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 285/333 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, YouTube, Google Patents, Google Scholar
Search terms used: thread, form, load, flank, stab, angle, crest, root, degrees, radius

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>
</table>

Further documents are listed in the continuation of Box C.

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