The New 4-Strand Light-Weight Torque-Balanced Hybrid Rope For Offshore Winching Applications

Update on the latest product development efforts for the 4-strand hybrid rope at WireCo

Presented by: Bamdad Pourladian, Ph.D.
Director Product Development

Presented to RVOC on April 25th, 2012
The Cross-Section of the 4-Strand Hybrid Rope

Presented to RVOC on April 25th, 2012
MACWHYTE oceanographic ropes.

Proven products in the toughest conditions

NILSPIN™

NILSPIN was engineered specifically for underwater applications. With its phenomenal resistance to kinking, corrosion, abrasion and fatigue, NILSPIN is a significant improvement over regular 3x19 oceanographic ropes.

Following the success of our plastic impregnated and coated SPACE-LAY wire rope on long and short term buoy implants, our engineers have designed the ideal underwater rope combining the unique antikink and corrosion resisting properties of regular SPACE-LAY with outstanding anti-rotational characteristics, high yield strength, low stretch and low weight in water.

NILSPIN can help you achieve a dramatic increase in service life

- Highly resistant to kinking
- Excellent strength/weight ratio in water
- Superior resistance to corrosion
- Will not peel—in the patented SPACE-LAY design, outer coating is an integral part of rope
- Effective impregnation forms water block—in event of accidental damage to coating
- Smooth surface reduces wear on sheaves and equipment
- Made from galvanized wire rope

### NILSPIN
(Special 3x19 SPACE-LAY construction)

<table>
<thead>
<tr>
<th>Rope Diameter</th>
<th>O.D. of</th>
<th>Minimum Breaking Force</th>
<th>Approx. Wt. Lbs./100'</th>
<th></th>
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<tbody>
<tr>
<td>Inches</td>
<td>Coating</td>
<td>in Air</td>
<td>in Sea</td>
<td>in Water</td>
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<td>1/8</td>
<td>3/16</td>
<td>1,810</td>
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<td>2.27</td>
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<td>3/16</td>
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<td>1/4</td>
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<td>6,650</td>
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<td>9.46</td>
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<td>9,960</td>
<td>21.9</td>
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<td>18,800</td>
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<td>23/32</td>
<td>30,700</td>
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<td>44.8</td>
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<tr>
<td>5/8</td>
<td>25/32</td>
<td>37,700</td>
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<td>56.2</td>
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<td>3/4</td>
<td>15/16</td>
<td>53,900</td>
<td>113.0</td>
<td>82.7</td>
</tr>
</tbody>
</table>

### END FITTINGS AND SEALING

These suggested end fittings and sealing are subject to specific environmental stresses. Consultation on end terminals and their relative efficiencies is recommended.

#### HOT SOCKETS
Remove plastic by rotary brushing, making sure plastic remains intact where it passes into socket throat. Attach in usual manner.

#### SWAGED FITTINGS
Factory installation recommended. If sealing is necessary, a plastic tape can be factory applied.

#### WIRE ROPE CLIPS
Use one more than recommended for bare rope. Retighten after load has been applied and inspect periodically for tightness and plastic condition. If corrosive conditions at the fittings are severe, another type of terminal should be used. There is no known effective seal to prevent damage that can be caused where the clips' pressure bears against the plastic. Thimble in eye is recommended.
TORQUE-BALANCED™

When you need higher strength and performance in wire rope.

It’s non-twisting.
Torque-Balanced wire rope resists rotation. At loads approaching the elastic limit—75% of rope breaking load—tests show rotation to be less than 1° per foot of rope length. Even when there is a sudden release of load, Torque-Balanced wire ropes will not kink or form loops and hockles, as in conventional 6-strand wire ropes. Torque-Balanced wire rope will give you better and longer service life free of the problems associated with conventional wire ropes in undersea operations.

It’s strong.
The elastic limit of Torque-Balanced wire rope is 75% of normal rope breaking load, compared to approximately 50% for 6-strand ropes. The importance is that the payload of a Torque-Balanced wire rope, at the elastic limit, is 50% greater than that of an equal strength 6-strand rope with no difference in diameter. Additionally, since a Torque-Balanced wire rope weighs less (about 10%) than a conventional 6-strand rope of the same size and strength, it has a much higher strength to weight ratio.

Specify: Bright, Galvanized or Jacketed wire rope.

<table>
<thead>
<tr>
<th>Size</th>
<th>Construction</th>
<th>Weight in Air Lbs/Ft</th>
<th>Approx. Elastic Limit Lbs</th>
<th>Minimum Breaking Force Lbs</th>
<th>0.2% Yield Strength Lbs</th>
<th>Maximum Length Feet</th>
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<tr>
<td>3/16</td>
<td>2x19 Scale</td>
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<td>98,000</td>
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<td>3x19 Scale</td>
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<td>22,500</td>
<td>23,600</td>
<td>77,000</td>
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<td>57,800</td>
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<td>43,000</td>
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<td>3x19 Scale</td>
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<td>30,225</td>
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<td>62,000</td>
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<td>3/16</td>
<td>3x46 Scale FW</td>
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<td>43,000</td>
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<td>7/32</td>
<td>3x46 Scale FW</td>
<td>1.27</td>
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<td>78,000</td>
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<td>19,000</td>
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<td>3.69</td>
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<td>222,000</td>
<td>195,000</td>
<td>10,800</td>
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</table>

Presented to RVOC on April 25th, 2012
The cross-section of the 3X19 all steel rope

The strength-to-weight ratio for 9/16” 3X19 is 66,057 pounds/(lbs/ft)
United States Patent

Adams et al.

TORQUE BALANCED ROPE

Inventors: William E. Adams, Hamden, Wilber
A. Lucht, Orange, both of Conn.

Assignee: United States Steel Corporation, Pittsburgh, Pa.

Appl. No.: 717,310

Filed: Aug. 24, 1976

Related U.S. Patent Documents

Reissue of:

Patent No.: 3,274,619
Issued: Mar. 26, 1966
Appl. No.: 545,726
Filed: Apr. 27, 1966

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Primary Examiner—Donald Watkins
Attorney, Agent, or Firm—Forest C. Sexton

ABSTRACT

A torque balanced regular lay wire rope having from three to six strands spiraled together such that the angle of lay of the outer wires in each strand is at least two times greater than the angle of lay of the strands in the rope and said rope is in a stress relieved condition.

9 Claims, 2 Drawing Figures
One way to increase strength-to-weight ratio is by using compacted strand ropes.
The cross-section of the compacted strand 4-strand rope (XLT4)

4X31   XLT4

The Strength-to-Weight ratio for 9/16” 4X31 is 68,615 pounds/(lbs/ft)

MBF = 44,600 pounds (37% higher than the required 32,500 pounds)

Wt/ft = 0.650 lbs/ft (32% heavier than 3X19)
The 4 X 16 hybrid rope

<table>
<thead>
<tr>
<th>Rope Construction</th>
<th>Required MBF</th>
<th>Weight in air</th>
<th>% Reduction of weight compared to 3 X 19 all steel rope</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/16” 3X19 (all steel)</td>
<td>32,500 pounds</td>
<td>0.492 lbs/ft</td>
<td>0%</td>
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<tr>
<td>Torque-Balanced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/16” 4X16 Hybrid</td>
<td>32,500 pounds</td>
<td>0.346 lbs/ft</td>
<td>30%</td>
</tr>
<tr>
<td>Torque-Balanced</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Presented to RVOC on April 25th, 2012
A typical winch operating with a 3X19 all steel wire rope

Presented to RVOC on April 25th, 2012
What properties are most desirable for this application?

- Higher strength-to-weight ratio
- Axial stiffness measured as EA
- Torque-Balance as measured by torque factor and turns per 1000d
- Better bending fatigue resistance? What D/d? How many bends per year?
- Axial tension-tension fatigue? What maximum and minimum loads and how many cycles per year?
- Multilayer winding (MLW) crush-resistance as well as fatigue-resistance?
FINAL REPORT

on

PERFORMANCE TESTS OF 3 X 19 WIRE ROPES MANUFACTURED BY
WIRE ROPE CORPORATION OF AMERICA

to

Woods Hole Oceanographic Institution
Purchase Order K109323

30 November 2005
Report Number FR-2967

by
Sarah A. Kelley, Frank Lee, and Philip T. Gibson

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Huntington Beach, CA. 92649-1616
714-898-5641  Fax: 714-893-1925
www.tmtlabs.com

Presented to RVOC on April 25th, 2012
FINAL REPORT

on

PERFORMANCE TESTS OF HYBRID XLT4 WIRE ROPE

to

WireCo WorldGroup
Purchase Order 94469

March 24, 2012
Report Number FR-3592

by

Philip T. Gibson and Henry A. Hobus

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Strength-to-weight ratio comparison

The strength-to-weight ratio for 9/16” 3X19 is 66,057 pounds/(lbs/ft)

The strength-to-weight ratio for 9/16” 4 X16 hybrid rope is 93,930 pounds/(lbs/ft)
Axial stiffness comparison

The EA for 9/16” 3X19 is 2,857,143 pounds)/(in/in) Measured between 3,000 and 13,000 pounds

The EA for 9/16” 4 X16 hybrid rope is 1,904,762 (pounds)/(in/in) Measured between 3,000 and 13,000 pounds

Presented to RVOC on April 25th, 2012
Torque-Factor comparison

The following is a formula that is used to calculate the induced torque in a wire rope under tensile load:

\[ T = k \cdot d \cdot F \]

where:

- \( T \) = Induced torque (N.m) or (ft-lbs)
- \( k \) = Torque Factor (Dimensionless)
- \( d \) = Rope diameter (m) or (ft)
- \( F \) = Tensile load (N) or (lbs)
Typical Torque-Factor (k) values

Typical Torque-Factor (k) values measured at 20%MBF for various wire ropes are as follows:

- 6-Strand IWRC ropes                  k = 0.08
- 6-Strand Fiber Core ropes          k = 0.09
- 8-Strand IWRC Regular Lay        k = 0.10
- 19X7 rotation-resistant rope       k = 0.045
- 35 X 7 rotation-resistant ropes   k = 0.005 to 0.02
- XLT4 crane ropes                         k = 0.02 to 0.025
Torque-Factor ($k$) comparison

The $k$ value for 9/16” 3X19 rope is 0.002
Measured at 20% MBF

The $k$ value for 9/16” 4 X16 hybrid rope is 0.016
Measured at 20% MBF

Presented to RVOC on April 25th, 2012
Torque-Factor ($k$) was measured for 6 different experimental hybrid rope prototypes also in WireCo’s laboratory in Germany.

![4x16 Hybrid rope k-factor graph](attachment:graph.png)

Presented to RVOC on April 25th, 2012
Typical Torque-Factor (k) values

Typical Torque-Factor (k) values measured at 20%MBF for various wire ropes are as follows:

- 6-Strand IWRC ropes $k = 0.08$
- 6-Strand Fiber Core ropes $k = 0.09$
- 8-Strand IWRC Regular Lay $k = 0.10$
- 19X7 rotation-resistant rope $k = 0.045$
- 35 X 7 rotation-resistant ropes $k = 0.005$ to $0.02$
- XLT4 crane ropes $k = 0.02$ to $0.025$
Rotation under tension load comparison - TMT’s test setup

FIGURE 1. TETR TEST APPARATUS
Rotation under tension load comparison - TMT measurements

The rotation for 9/16” 3X19 rope is 0.26 turns per 1000d Measured at 45% MBF

The rotation for 9/16” 4 X16 hybrid rope is 7 turns per 1000d Measured at 45% MBF

Presented to RVOC on April 25th, 2012
Rotation under tension load - ISO standard 21669 test procedure

Figure 1 — Typical method of securing a test piece at the upper end

Turns (360 degrees) per 1000d is measured at a tension load of 20%MBF

Presented to RVOC on April 25th, 2012
Cyclic Bend Over Sheave (CBOS) fatigue test - TMT’s test setup

FIGURE 2. CBOS FATIGUE TEST APPARATUS
Cyclic Bend Over Sheave (CBOS) fatigue test - TMT’s test setup

**TABLE 4. TEST SHEAVES**

<table>
<thead>
<tr>
<th>d Nominal Rope Diameter, inch</th>
<th>TD Sheave Tread Diameter, inches</th>
<th>PD Sheave Pitch Diameter, inches</th>
<th>PD/d</th>
<th>GD Sheave Groove Diameter, inch</th>
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</thead>
<tbody>
<tr>
<td>9/16</td>
<td>16.312</td>
<td>16.875</td>
<td>30</td>
<td>0.590</td>
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</table>
Cyclic Bend Over Sheave (CBOS) fatigue test comparison - TMT’s test results

<table>
<thead>
<tr>
<th>TMT Sample Number</th>
<th>Tension, pounds</th>
<th>Cycling Stroke, inches</th>
<th>Bend Cycles Completed Before Break</th>
<th>Location of Break</th>
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</thead>
<tbody>
<tr>
<td>64</td>
<td>13,000</td>
<td>48</td>
<td>5,242</td>
<td>1 Strand Broke in the DBZ</td>
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<tr>
<td>A4</td>
<td>13,000</td>
<td>48</td>
<td>7,630</td>
<td>1 Strand Broke in the DBZ</td>
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</table>
Cyclic Bend Over Sheave (CBOS) fatigue test- ongoing reverse-bend-fatigue (RBF) tests
Cyclic Bend Over Sheave (CBOS) fatigue test - ongoing simple bend fatigue tests
Cyclic Bend Over Sheave (CBOS) fatigue test - ongoing simple bend fatigue tests

Test conditions: D/d = 20
Applied tension = 20%MBF

Rope lubrication: light oil to dry

Bending cycles to removal criteria = 6,400

Remaining strength after removal = 95%MBF

Bending cycles to complete failure = 18,476

Presented to RVOC on April 25th, 2012
Tension-tension fatigue test comparison - TMT’s test results

<table>
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<tr>
<th>TMT Sample Number</th>
<th>Tension, pounds</th>
<th>Load Cycles Completed</th>
<th>Rope Condition After Test Completion</th>
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<tr>
<td>69</td>
<td>50 - 13,000</td>
<td>22,573</td>
<td>Broke at the Nose of a Termination</td>
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<td>A3</td>
<td>50 - 13,000</td>
<td>12,163</td>
<td>One strand broken at nose of socket</td>
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<tr>
<td>A7</td>
<td>50 - 13,000</td>
<td>10,368</td>
<td>Near nose of socket</td>
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</table>
Multilayer winding (MLW) tests at University of Stuttgart

- A 500 ft experimental length of 16mm hybrid 4-strand rope has been scheduled
- MLW tests will be conducted at the University of Stuttgart in Germany
- What other properties should be evaluated and optimized?
End attachments for the 4-strand hybrid rope
The advantages of the 4-strand hybrid hoist rope

- Higher strength-to-weight ratio: A significant reduction in rope weight while maintaining a high strength.

- Better bending fatigue resistance than 3 X 19

- The first experimental version of 4-strand rope has shown a reasonably good “torque-factor” values (k value lower than 0.02)
Next steps

► Additional tests are ongoing in order to fine tune rotation and torque factor properties
► Complete the RBF tests
► Test the effect of various lubricants on the bending fatigue performance
► MLW tests will be conducted on a 16mm experimental production run of 4X16 hybrid rope
► A short experimental length of 3-strand hybrid rope will be produced and tested for improved rotational properties
► What sort of field trials can be conducted? What length of rope may be needed?
Thank you very much for your attention! Any questions?