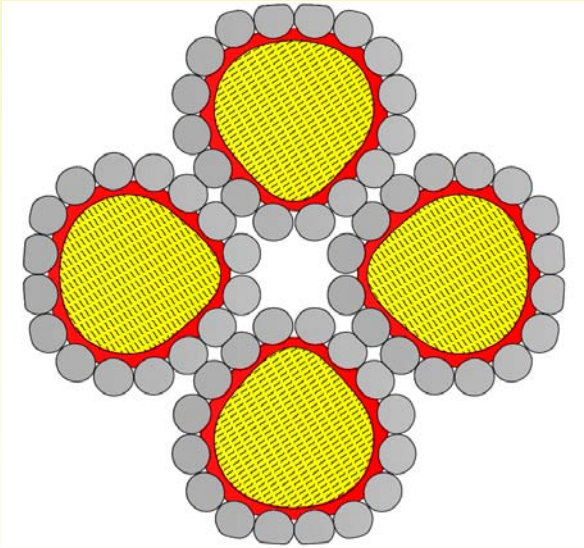
The New 4-Strand Light-Weight Torque-Balanced Hybrid Rope For Offshore Winching Applications

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



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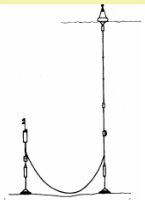
MACWHYTE oceanographic ropes.

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***

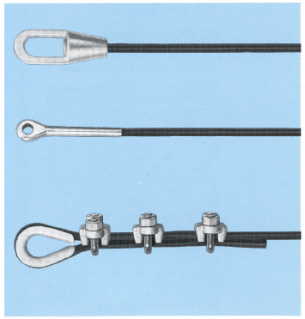
- Highly resistant to kinking
- Excellent strength/weight ratio in water
- Superior resistance to corrosion
- Will not peel—in the patented SPACE-LAY design, outer coating is an integral part of rope
- Effective impregnation forms water block—in event of accidental damage to coating
- Smooth surface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

NILSPIN
(Special 3x19 SPACE-LAY construction)

Rope Diameter Inches	O.D. of Covering Inches	Minimum Breaking Force	Approx. Wt. Lbs./100' In Air	In Sea Water
1/8	3/16	1,870	3.50	2.27
5/32	7/32	2,840	5.23	3.56
3/16	1/4	4,000	7.37	5.19
1/4	5/16	6,650	12.9	9.46
5/16	7/16	9,900	21.0	14.3
3/8	1/2	13,900	30.0	21.3
7/16	9/16	18,800	39.2	28.1
1/2	21/32	24,400	51.7	36.7
9/16	23/32	30,700	62.8	44.8
5/8	25/32	37,700	77.5	56.2
3/4	15/16	53,900	113.0	82.7

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.

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TORQUE-BALANCED™

When you need higher strength and performance in wire rope.

It's non-twisting.

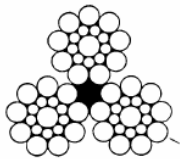
Torque-Balanced wire rope resists rotation. At loads approaching the elastic limit—75% of rope breaking load—tests show rotation to be less than 1° per foot of rope length. Even when there is a sudden release of load, Torque-Balanced wire ropes will not kink or form loops and hockles, as in conventional 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.

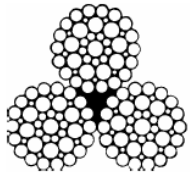
The elastic limit of Torque-Balanced wire rope is 75% of normal rope breaking load, compared to approximately 50% for 6-strand ropes. The importance is that the payload of a Torque-Balanced wire rope, at the elastic limit, is 50% greater than that of an equal strength 6-strand rope with no difference 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.

Size Inches	Construction	Weight in Air Lbs/Ft	Approx. Elastic Limit Lbs	Minimum Breaking Force Lbs	0.2% Yield Strength Lbs	Maximum Length Feet
3/16	3x19 Seale	.0586	3,000	4,000	3,500	50,000
1/4	3x19 Seale	.0997	5,036	6.750	5,900	45,000
5/16	3x19 Seale	.153	7,725	10.300	9,100	30,000
3/8	3x19 Seale	.220	11,100	14,800	13,000	50,000
7/16	3x19 Seale	.304	15,000	20,000	17,600	42,000
1/2	3x19 Seale	.392	19,275	25,700	22,600	98,000
9/16	3x19 Seale	.492	24,375	32,500	28,600	77,000
5/8	3x19 Seale	.602	30,225	40,300	35,500	62,000
3/4	3x19 Seale	.879	43,350	57,800	50,900	43,000
7/8	3x19 Seale	1.21	58,500	78,000	68,600	32,000
1	3x19 Seale	1.56	75,450	100,600	88,500	24,000
1-1/8	3x19 Seale	1.96	93,000	124,000	109,000	19,000
1/2	3x41 Seale FW	.417	19,275	25,700	22,600	98,000
9/16	3x41 Seale FW	.517	24,375	32,500	28,600	77,000
5/8	3x41 Seale FW	.631	30,225	40,300	35,500	62,000
3/4	3x46 Seale FW	.903	43,350	57,800	50,900	43,000
7/8	3x46 Seale FW	1.27	58,500	78,000	68,600	32,000
1	3x46 Seale FW	1.64	75,450	100,600	88,500	24,000
1-1/8	3x46 Seale FW	2.07	93,000	124,000	109,000	19,000
1-1/4	3x46 Seale FW	2.60	118,500	158,000	139,000	15,500
1-3/8	3x46 Seale FW	3.10	141,000	188,000	165,000	12,900
1-1/2	3x46 Seale FW	3.69	166,500	222,000	195,000	10,800



3x19



3x46

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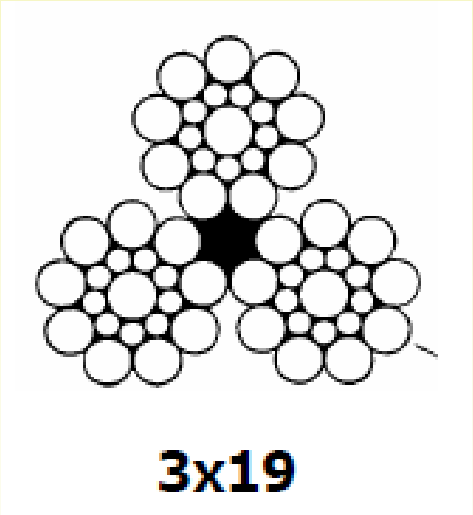
The cross-section of the 3X19 all steel rope



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

United States Patent [19]

Adams et al.

[11] E **Re. 29,537**

[45] Reissued **Feb. 14, 1978**

[54] **TORQUE BALANCED ROPE**

[75] Inventors: **William E. Adams**, Hamden; **Wilbert A. Lucht**, Orange, both of Conn.

[73] Assignee: **United States Steel Corporation**, Pittsburgh, Pa.

[21] Appl. No.: **717,310**

[22] Filed: **Aug. 24, 1976**

Related U.S. Patent Documents

Reissue of:

[64] Patent No.: **3,374,619**
Issued: **Mar. 26, 1968**
Appl. No.: **545,726**
Filed: **Apr. 27, 1966**

[51] **Int. Cl.**[2] **D07B 1/06**; D02J 13/00

[52] **U.S. Cl.** **57/148**

[58] **Field of Search** 57/139, 144, 145, 146, 57/147, 148, 149, 152

[56] **References Cited**

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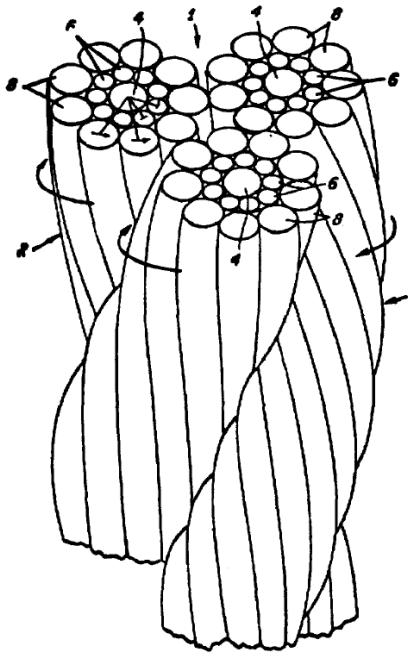
Primary Examiner—Donald Watkins
Attorney, Agent, or Firm—Forest C. Sexton

[57] **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



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One way to increase strength-to-weight ratio is by using compacted strand ropes

US006260343B1

(12) **United States Patent**
Pourladian

(10) **Patent No.: US 6,260,343 B1**
(45) **Date of Patent: Jul. 17, 2001**

(54) **HIGH-STRENGTH, FATIGUE RESISTANT STRANDS AND WIRE ROPES**

(75) Inventor: **Bamdad Pourladian**, St. Joseph, MO (US)

(73) Assignee: **Wire Rope Corporation of America, Incorporated**, St. Joseph, MO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/301,069**

(22) Filed: **Apr. 28, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/083,800, filed on May 1, 1998.

(51) **Int. Cl.**[7] **D02G 3/02**

(52) **U.S. Cl.** **57/200**; 57/13; 57/15; 57/139; 57/201; 57/206; 57/207; 57/210; 57/214; 57/248; 57/253; 174/113

(58) **Field of Search** 57/13, 15, 139, 57/200, 201, 206, 207, 210, 214, 248, 253, 145, 166, 161; 174/113

(56) **References Cited**

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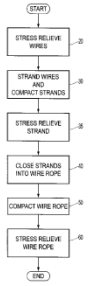
Primary Examiner—John J. Calvert
Assistant Examiner—Shaun R Hurley
(74) *Attorney, Agent, or Firm*—Oliff & Berridge, PLC

(57) **ABSTRACT**

Strands and wire ropes composed of materials such as high carbon steels and stainless steels can be provided in a compacted, mechanically stress relieved and thermally stress relieved condition. The wires are compacted during stranding to form the individual strands of the wire ropes. The wires can be thermally stress relieved prior to stranding to remove tensile residual stresses. Compaction produces a compressive residual stress state in the strands which increases fatigue resistance. The strands can be thermally stress relieved subsequent to closing. The wires and strands can be heated using a process such as induction heating. The wire ropes can be torque balanced or rotation resistant. The wire ropes have high strength, a high strength-to-weight ratio and enhanced fatigue life. Stainless steel wire ropes also provide corrosion resistance.

27 Claims, 3 Drawing Sheets



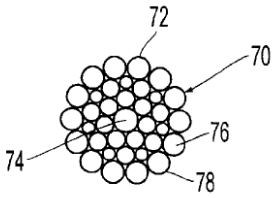


FIG. 3A

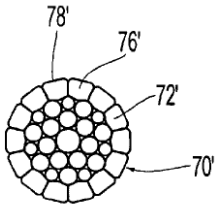


FIG. 3B

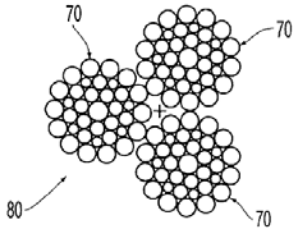


FIG. 4A

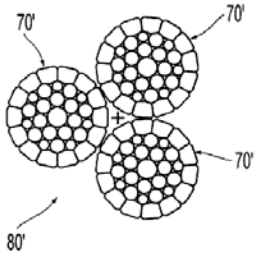


FIG. 4B

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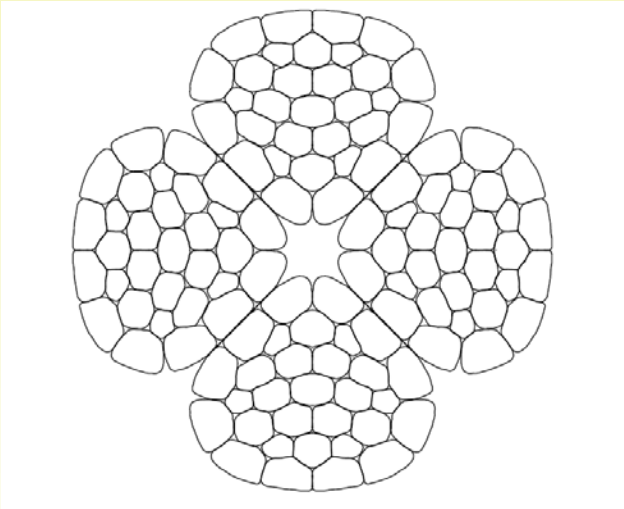
The cross-section of the compacted strand 4-strand rope (XLT4)



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)

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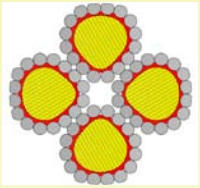
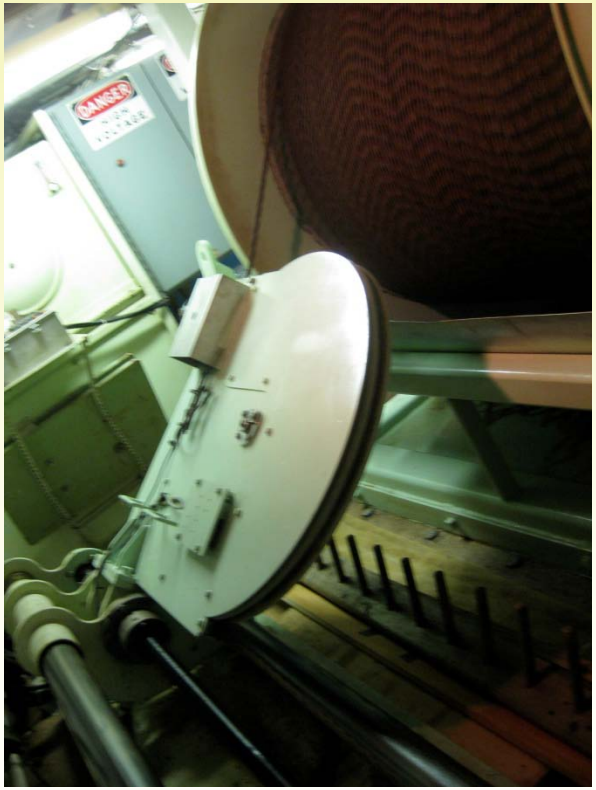
The 4 X 16 hybrid rope



Rope Construction	Required MBF	Weight in air	% Reduction of weight compared to 3 X 19 all steel rope
9//16" 3X19 (all steel) Torque-Balanced	32,500 pounds	0.492 lbs/ft	0%
9/16" 4X16 Hybrid Torque-Balanced	32,500 pounds	0.346 lbs/ft	**30%**

A typical winch operating with a 3X19 all steel wire rope



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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

PERFORMACE 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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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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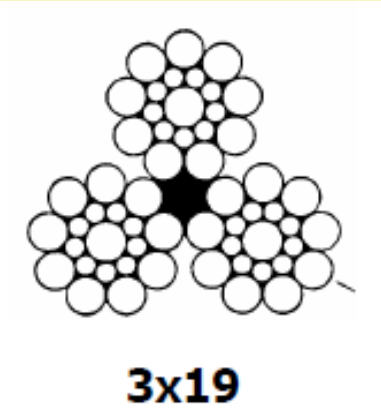
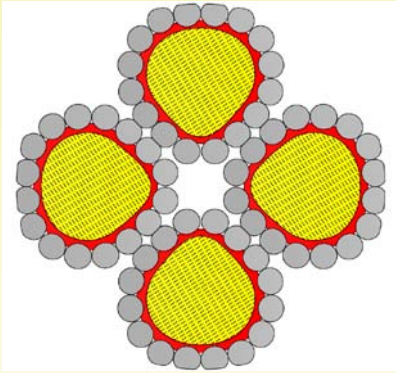
Strength-to-weight ratio comparison

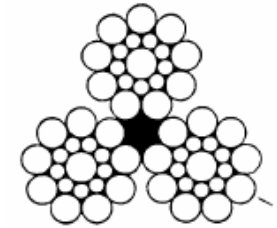


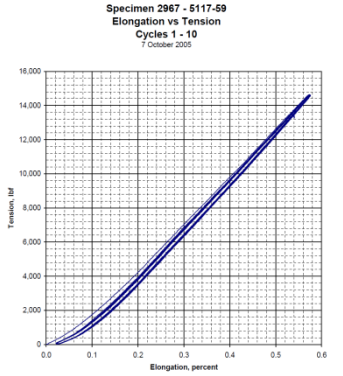
The strength-to-weight ratio for 9/16” 3X19 is **66,057 pounds/(lbs/ft)**



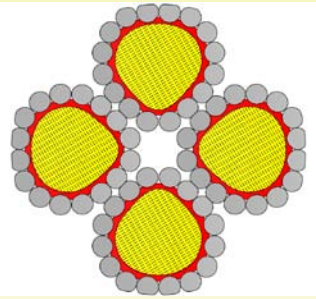
The strength-to-weight ratio for 9/16” 4 X16 hybrid rope is **93,930 pounds/(lbs/ft)**

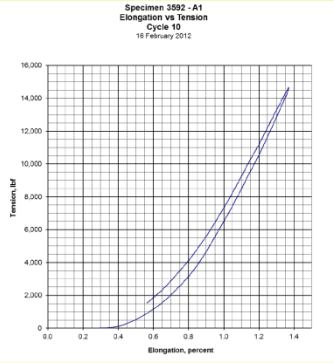
Axial stiffness comparison





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

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 . d . F

where:

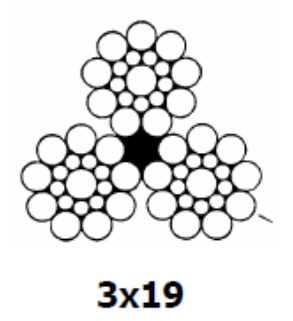
T = Induced torque (N.m) or (ft-lbs)
k = Torque Factor (Dimensionless)
d = Rope diameter (m) or (ft)
F = Tensile load (N) or (lbs)

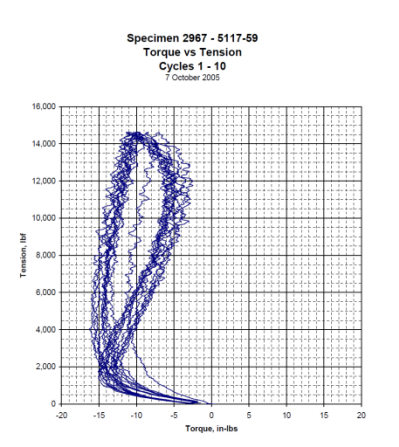
Typical Torque-Factor (k) values

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

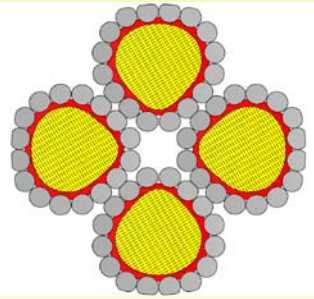
6-Strand IWRC ropes	**k = 0.08**
6-Strand Fiber Core ropes	**k = 0.09**
8-Strand IWRC Regular Lay	**k = 0.10**
19X7 rotation-resistant rope	**k = 0.045**
35 X 7 rotation-resistant ropes	**k = 0.005 to 0.02**
XLT4 crane ropes	**k = 0.02 to 0.025**

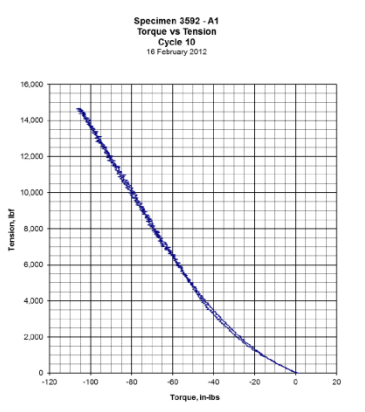
Torque-Factor (k) comparison





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

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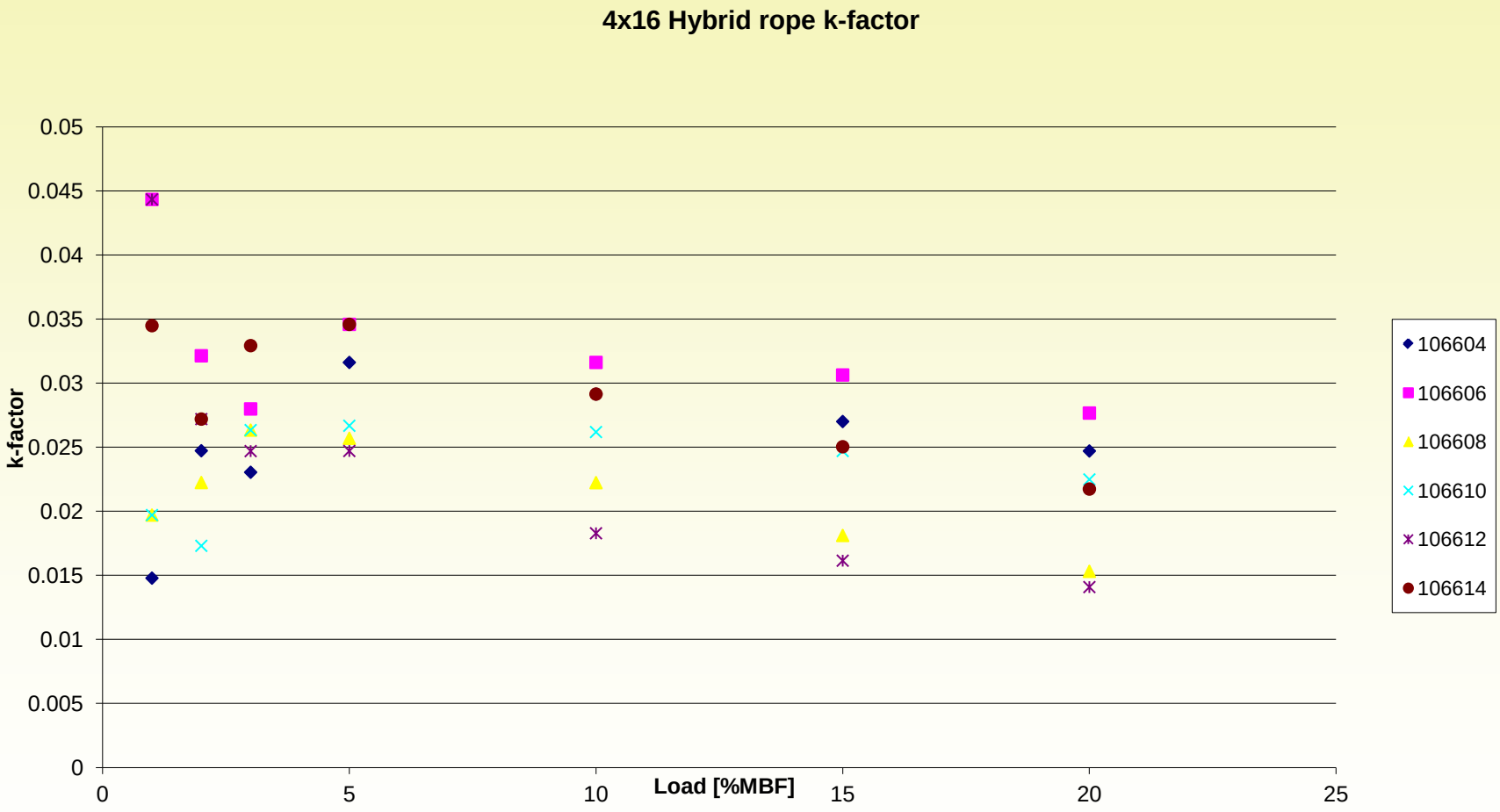
Torque-Factor (k) was measured for 6 different experimental hybrid rope prototypes also in WireCo's laboratory in Germany



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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

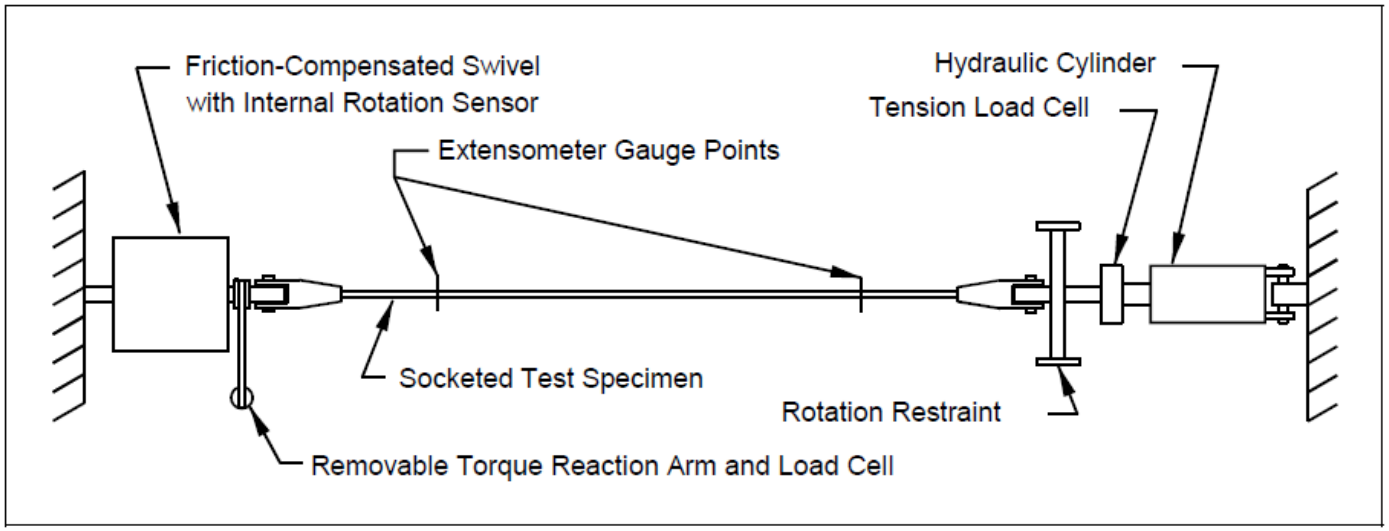
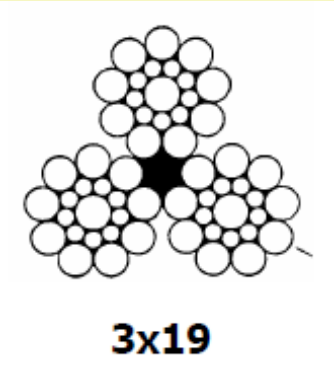
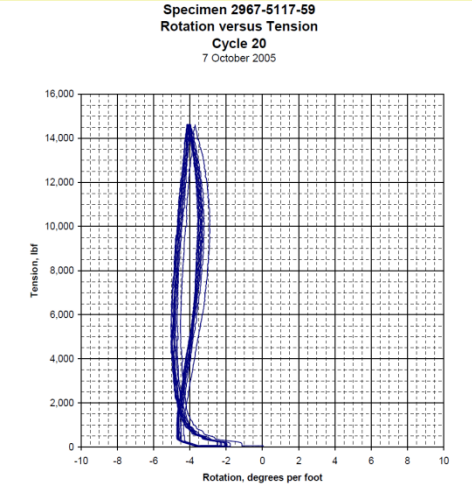
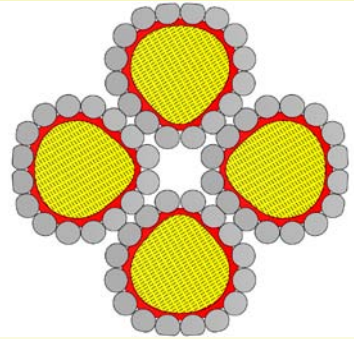


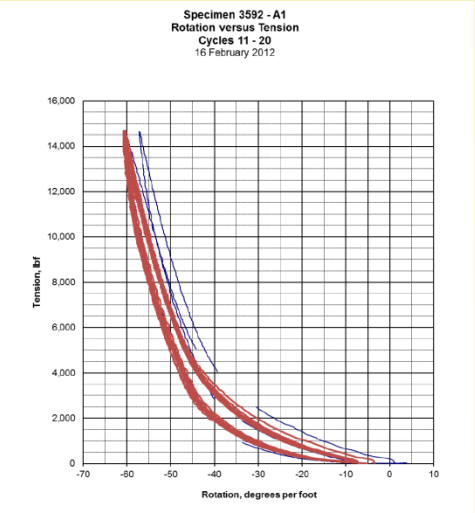
FIGURE 1. TETR TEST APPARATUS

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

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Rotation under tension load - ISO standard 21669 test procedure

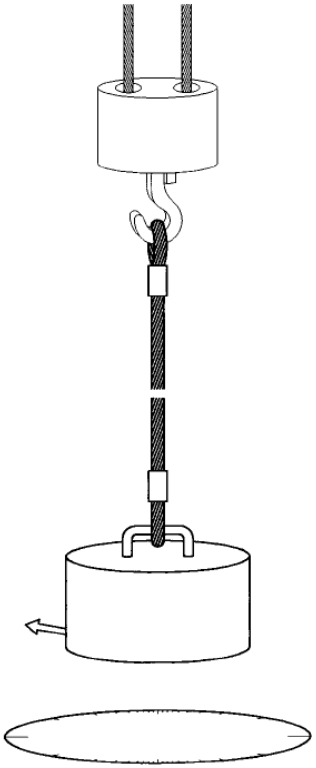


Figure 1 — Typical method of securing a test piece at the upper end

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

Cyclic Bend Over Sheave (CBOS) fatigue test- TMT's test setup

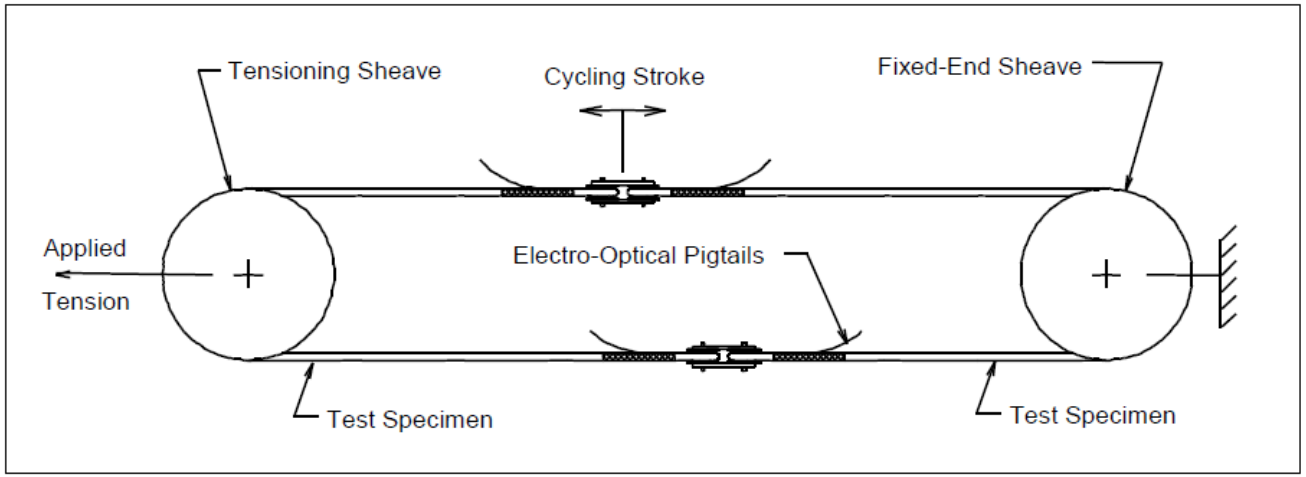


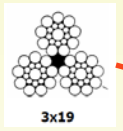
FIGURE 2. CBOS FATIGUE TEST APPARATUS

Cyclic Bend Over Sheave (CBOS) fatigue test- TMT's test setup

TABLE 4. TEST SHEAVES

d Nominal Rope Diameter, inch	TD Sheave Tread Diameter, inches	PD Sheave Pitch Diameter, inches	PD/d	GD Sheave Groove Diameter, inch
9/16	16.312	16.875	30	0.590

Cyclic Bend Over Sheave (CBOS) fatigue test comparison- TMT's test results



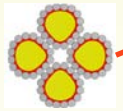


TABLE 5. CYCLIC BEND OVER SHEAVE TEST SUMMARY

TMT Sample Number	Tension, pounds	Cycling Stroke, inches	Bend Cycles Completed Before Break	Location of Break
64	13,000	48	5,242	1 Strand Broke in the DBZ
A4	13,000	48	7,630	1 Strand Broke in the DBZ

Cyclic Bend Over Sheave (CBOS) fatigue test- ongoing reverse-bend-fatigue (RBF) tests

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Cyclic Bend Over Sheave (CBOS) fatigue test- ongoing simple bend fatigue tests

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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**

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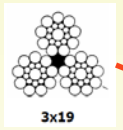
Tension-tension fatigue test comparison- TMT's test results



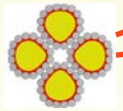


TABLE 6: CYCLIC TENSION TEST SUMMARY

TMT Sample Number	Tension, pounds	Load Cycles Completed	Rope Condition After Test Completion
69	50 - 13,000	22,573	Broke at the Nose of a Termination
A3	50 - 13,000	12,163	One strand broken at nose of socket
A7	50 - 13,000	10,368	Near nose of socket

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

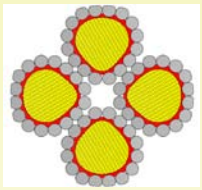
The advantages of the 4-strand hybrid hoist rope

- 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?



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