Life Cycle Testing of 3x19 Wire Rope

Shipboard Scientific Support Equipment: Oceanographic Cable
NSF Grant No. 0555000

Presented by Rick Trask (WHOI)

Topics

- Results of Bending Fatigue Tests conducted on 9/16” diameter 3x19 torque balanced wire rope.
- Experimental work on a technique for evaluating wire condition in the field.

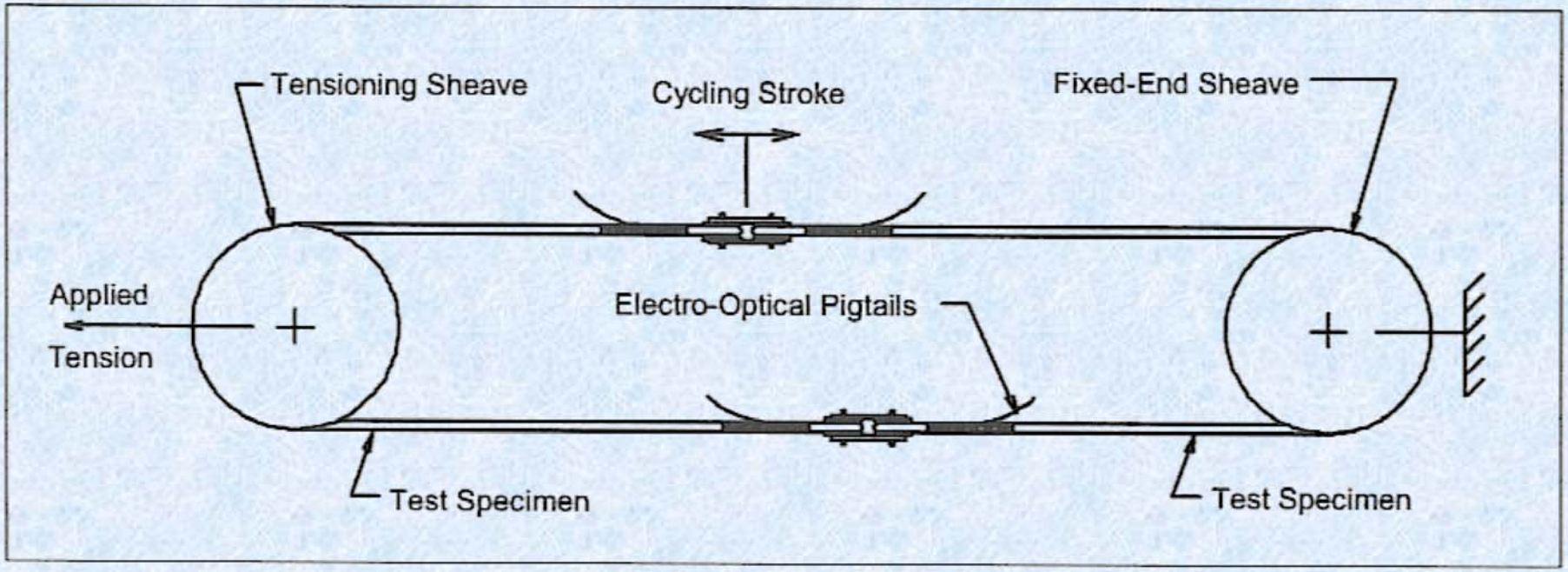
Bending Fatigue Tests

To assess the bending fatigue performance of new 9/16” Trawl wire

Bending Fatigue Tests

- Testing conducted by Tension Member Technology (TMT) under the direction of Phil Gibson
- Results obtained in late 2008
- What was tested ?
  - 9/16” diameter 3x19 Torque Balanced wire rope
  - Wire rope from WireCo World Group (current supplier of majority of wire pool 3x19 wire rope)
  - Test samples taken from a 1500 ft continuous length that was part of a 90,000 ft. wire rope order currently in wire pool inventory
  - Individual test pieces cut and terminated by TMT

CBOS Fatigue Test Apparatus



- Two samples tested at a time over pair of identical sheaves.
- Rope tension applied by hydraulic cylinder and monitored by strain gauge load cell.
- Samples were cycled back and forth over the sheaves using a variable speed electric motor attached to fixed end sheave

Test Parameters

- Tests conducted on pairs of sheaves of three specific pitch diameters so as to simulate (3) D/d ratios.

  (D/d =20, 30, and 40)

  D= Sheave Diameter d = rope diameter

- For each of the three D/d sheave configurations, tests conducted at (4) designated tensions:

	Safety Factor
Tension 1: 10% of Rope BS	10
Tension 2: 20% of Rope BS	5
Tension 3: 30% of Rope BS	3.3
Tension 4: 40% of Rope BS	2.5

Test Procedure

- New wire breaking strength determined from 3 samples.
- Test Program consisted of 4 Phases
- Phase 1 and 2
  - Two samples were cycled until one sample parted.
  - A buddy sample was then inserted to replace the parted sample so as to finish the test of the second sample.
  - For each of (3) D/d configurations, 2 wire samples were

    cycled at each of 4 tensions yielding 24 samples (Phase 1)
  - The number of bending cycles at the time of wire failure were logged for each sample.

Test Procedure (continued)

Phase 3

- Test set up was the same as that for Phase 1.
- Tests were stopped at the **half life** of the rope samples as determined in the previous tests (bend cycles to failure from Phase 1 and 2 divided by 2). Each of the samples was then pulled to break to determine the rope's residual breaking strength at the half life point.

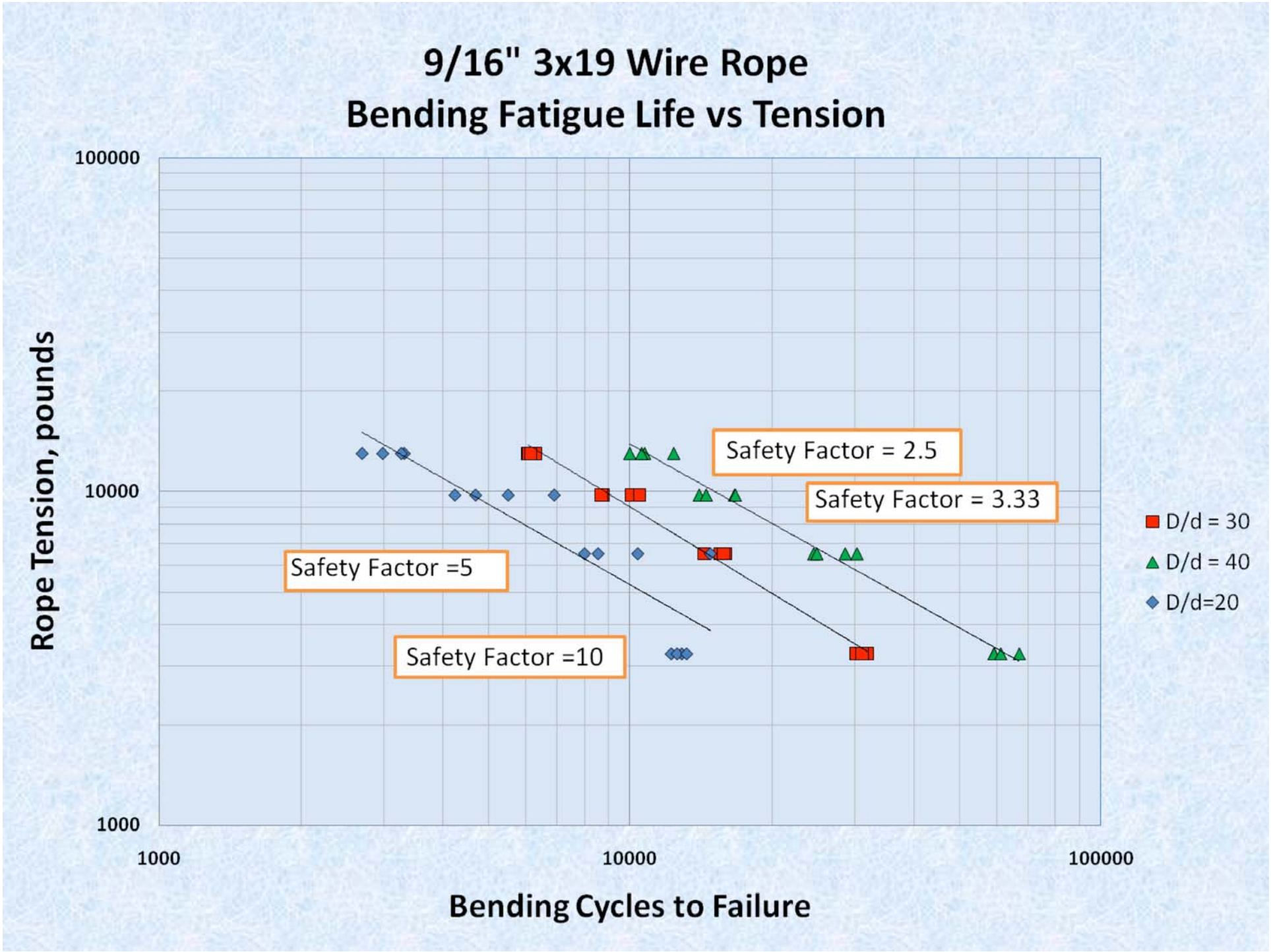
Test Procedure (continued)

Phase 4

- Same as Phase 3 except the test was stopped at **three-fourths** of the life of the rope samples as previously determined by the Phase 1 and 2 tests.

- Each of the samples was then pulled to break to determine the rope's residual breaking strength at the three-fourth's life point.

Results from Phase 1 and 2


9/16" 3x19 Wire Rope
Bending Fatigue Life vs Tension
Rope Tension, pounds
100000
10000
1000
1000
10000
100000
Bending Cycles to Failure
Safety Factor = 2.5
Safety Factor = 3.33
Safety Factor =5
Safety Factor =10
D/d = 30
D/d = 40
D/d=20

Results from Phase 3 and 4

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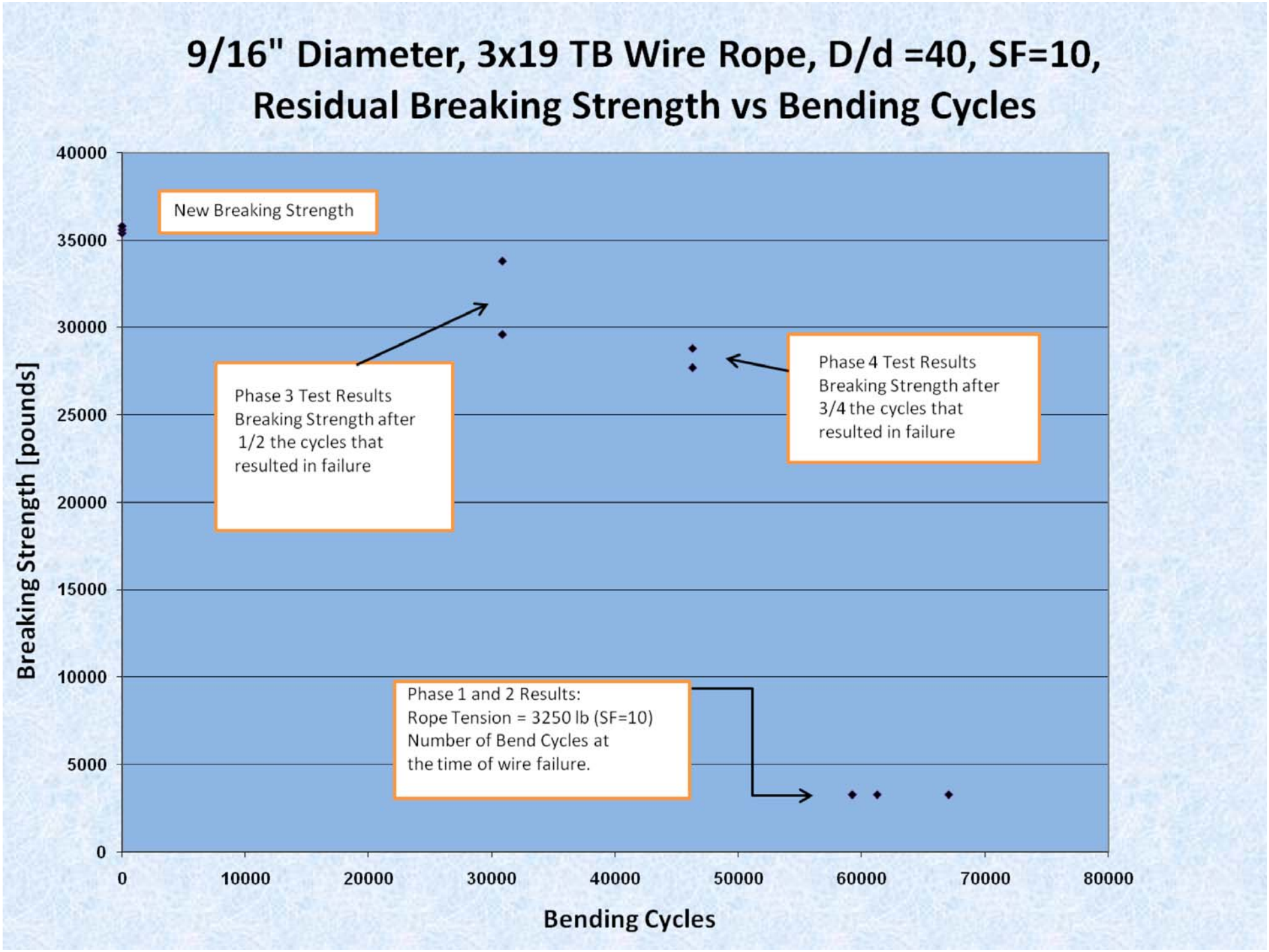
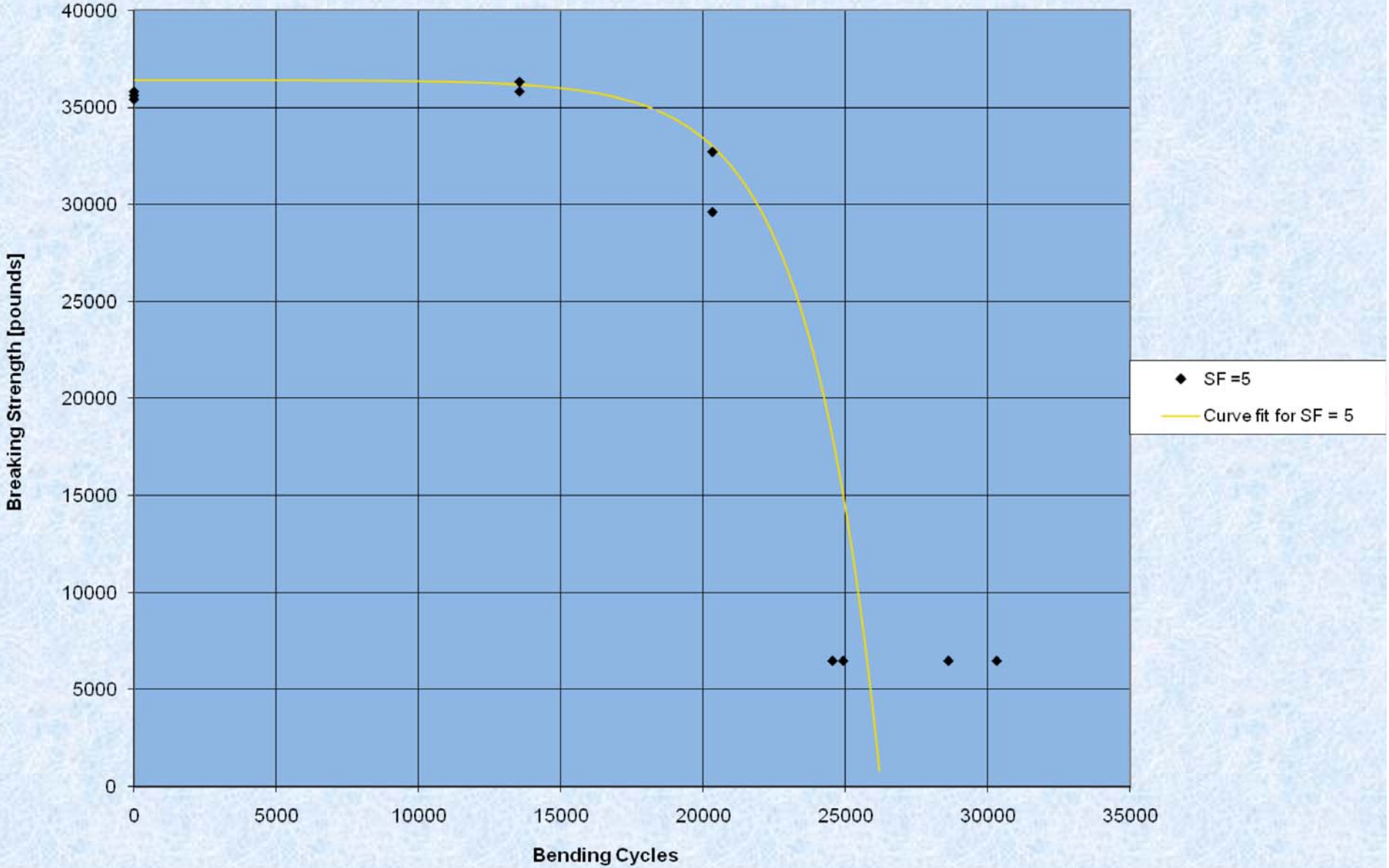
Effect of Decreasing Safety Factors on Bending Fatigue Life

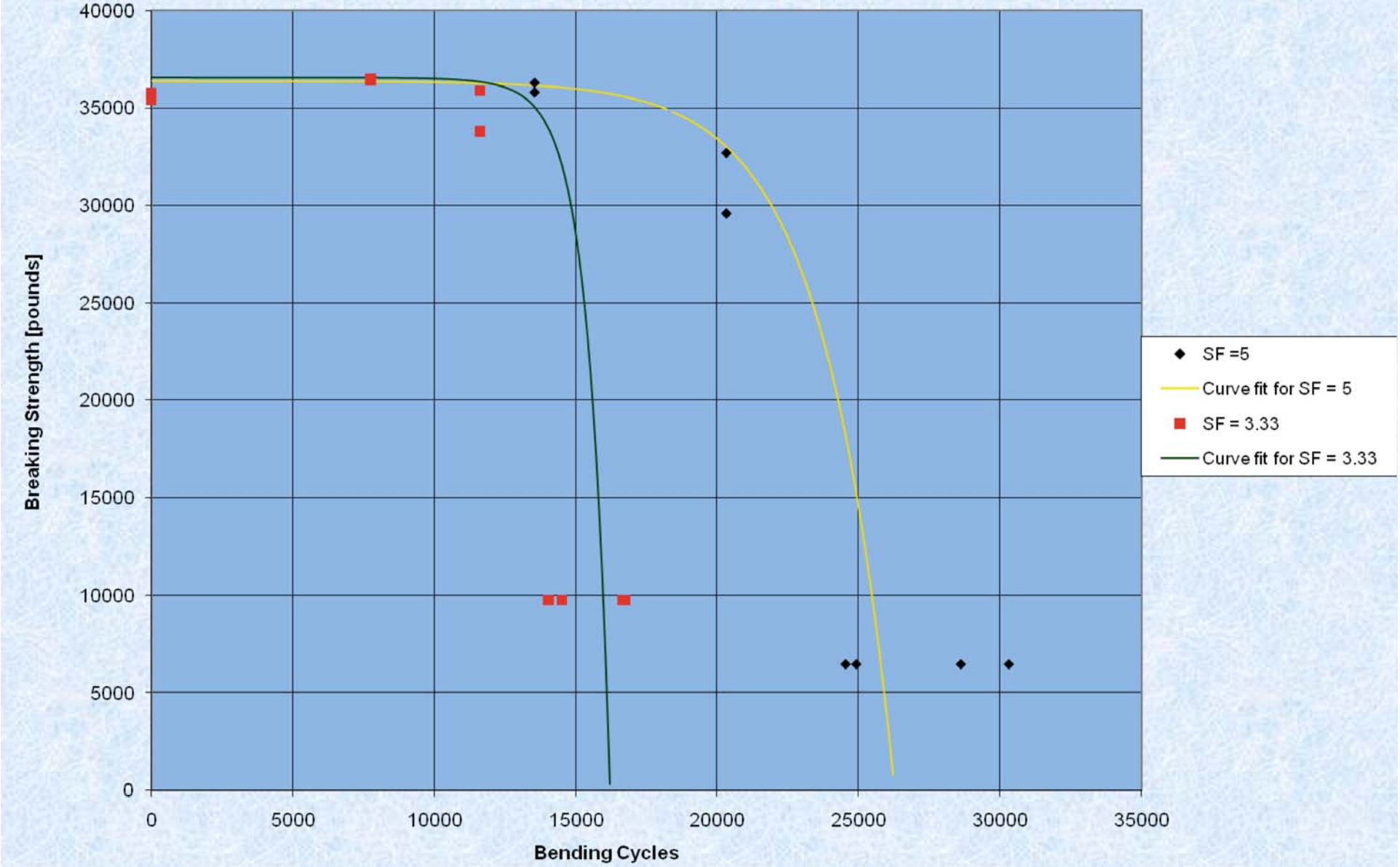
9/16" Diameter, 3x19 TB Wire Rope, D/d =40, SF=10, Residual Breaking Strength vs Bending Cycles



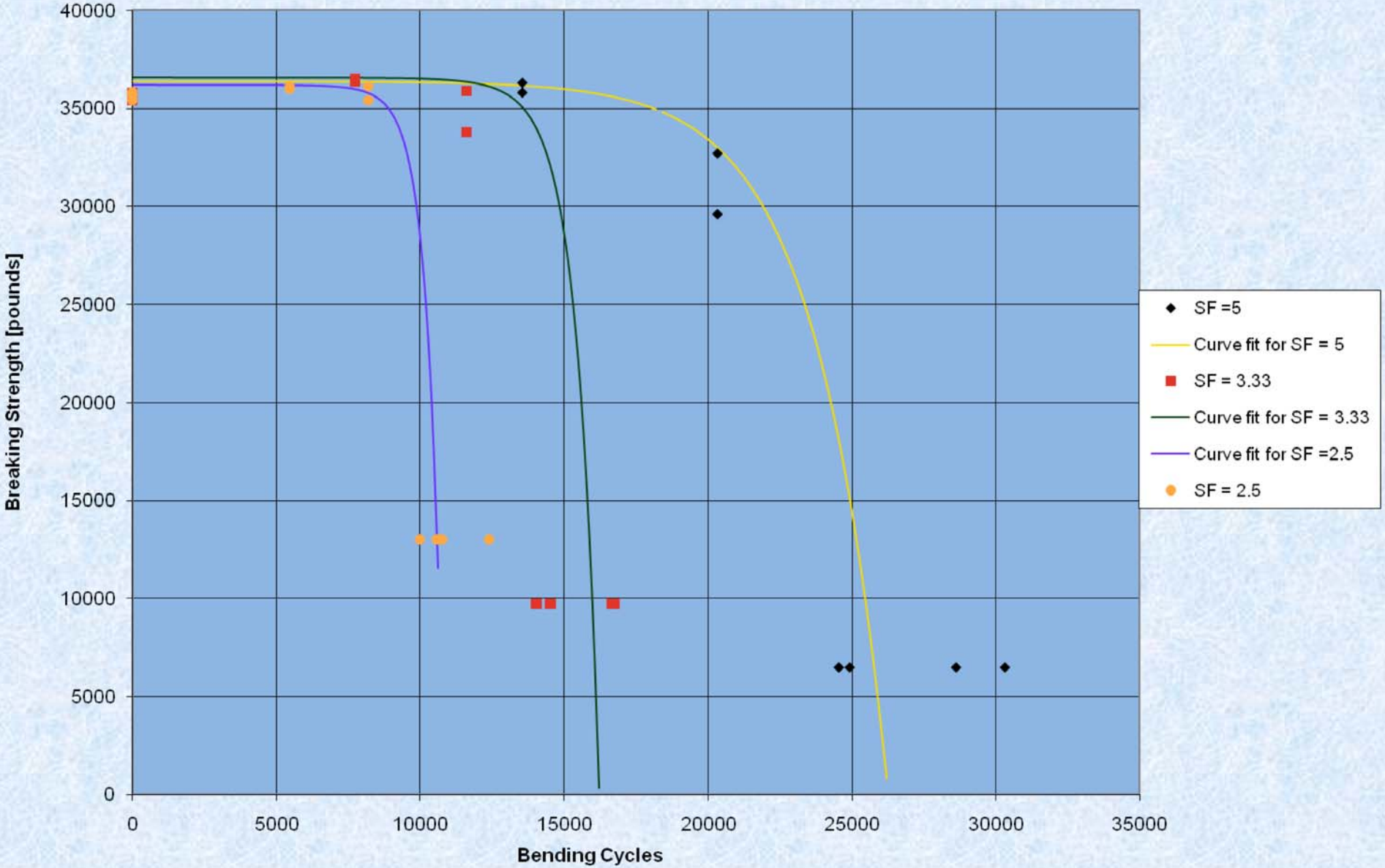
9/16" Diameter, 3x19 TB Wire Rope, D/d=40, SF=5, Residual Breaking Strength vs Bending Cycles



9/16” Diameter, 3 x 19 TB Wire Rope, D/d=40, SF=5 and 3.33
Residual Breaking Strength vs Bending Cycles

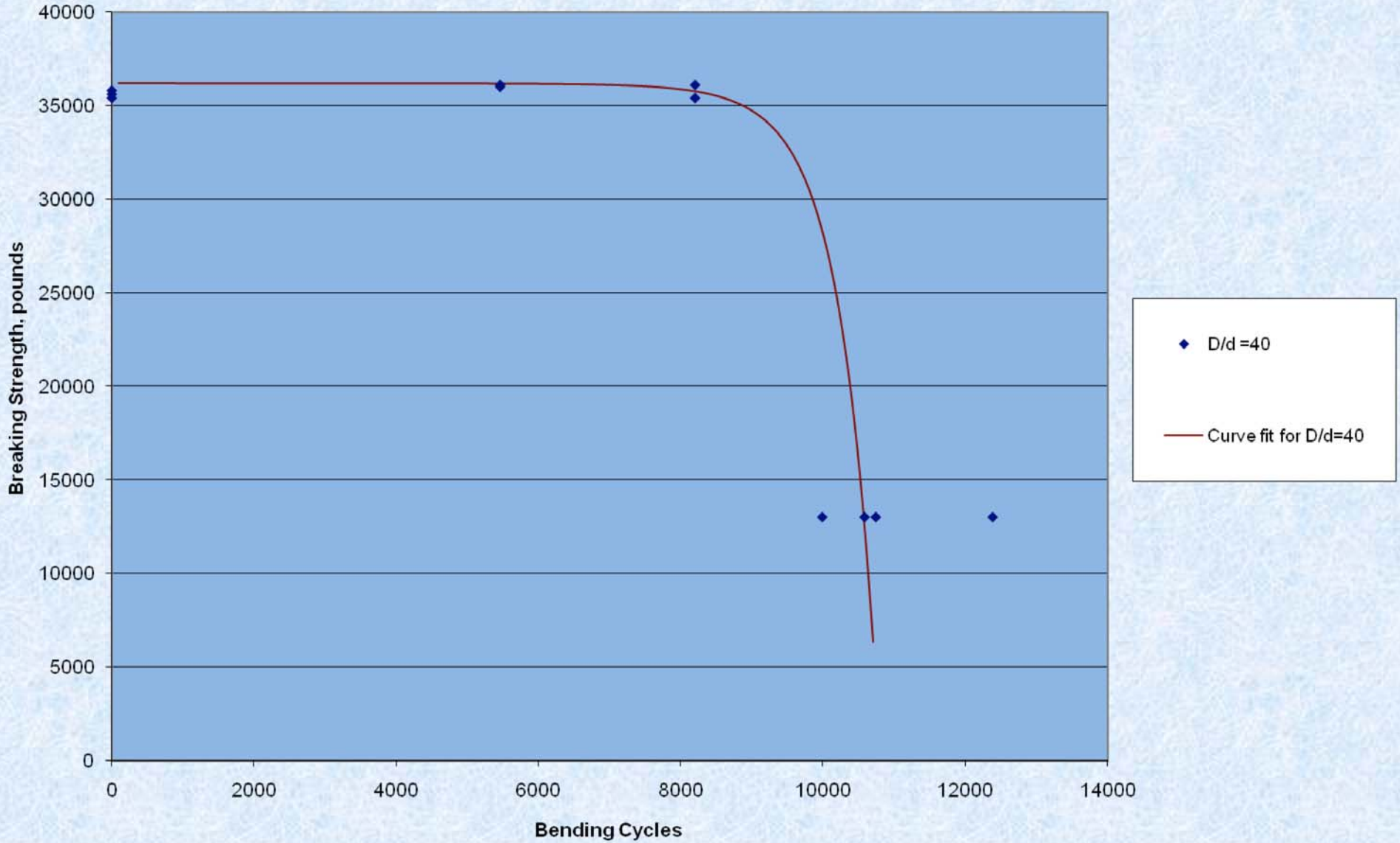


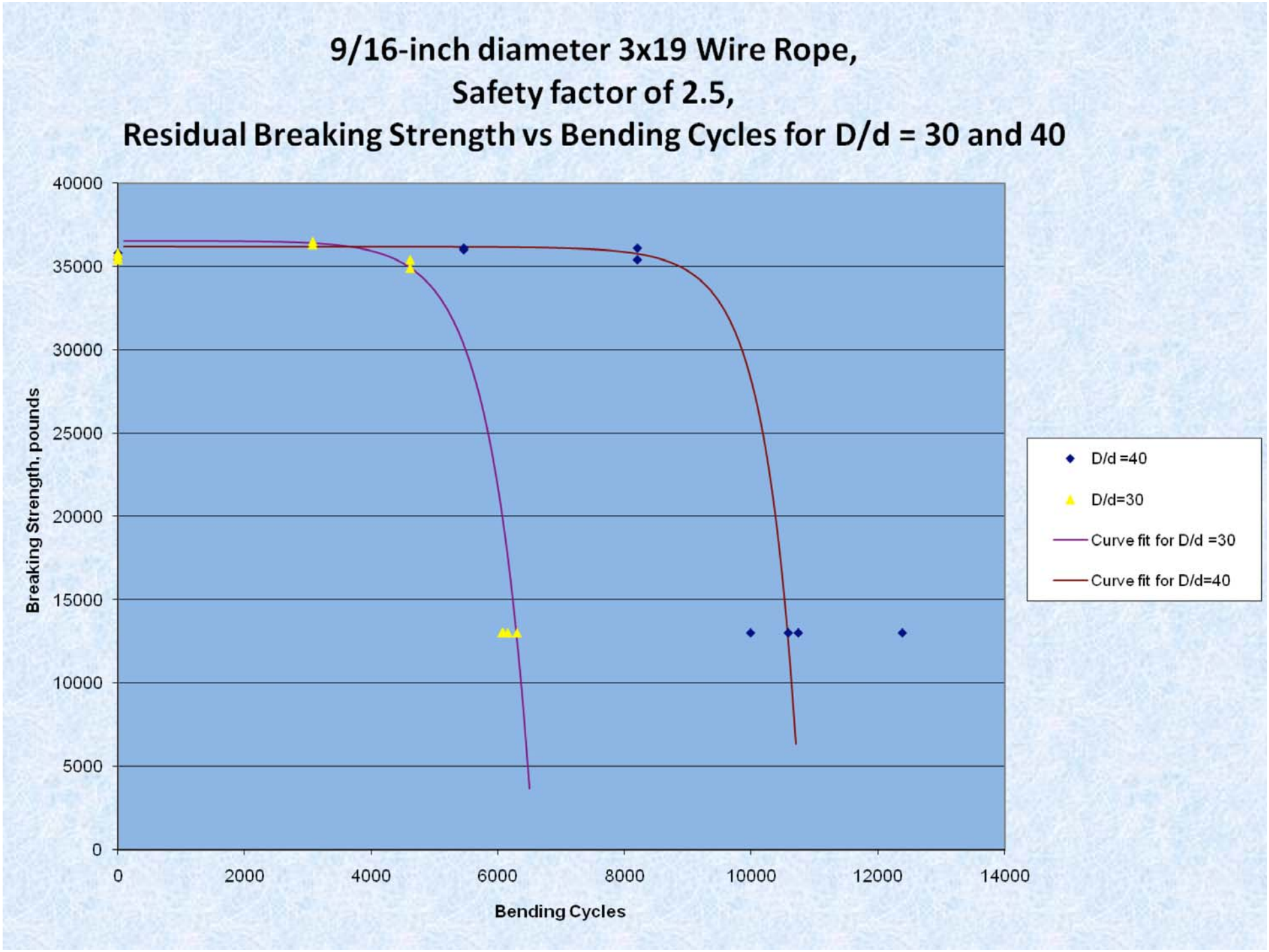
9/16” Diameter, 3 x 19 TB Wire Rope, D/d=40, SF=5.0, 3.33 and 2.5
Residual Breaking Strength vs Bending Cycles



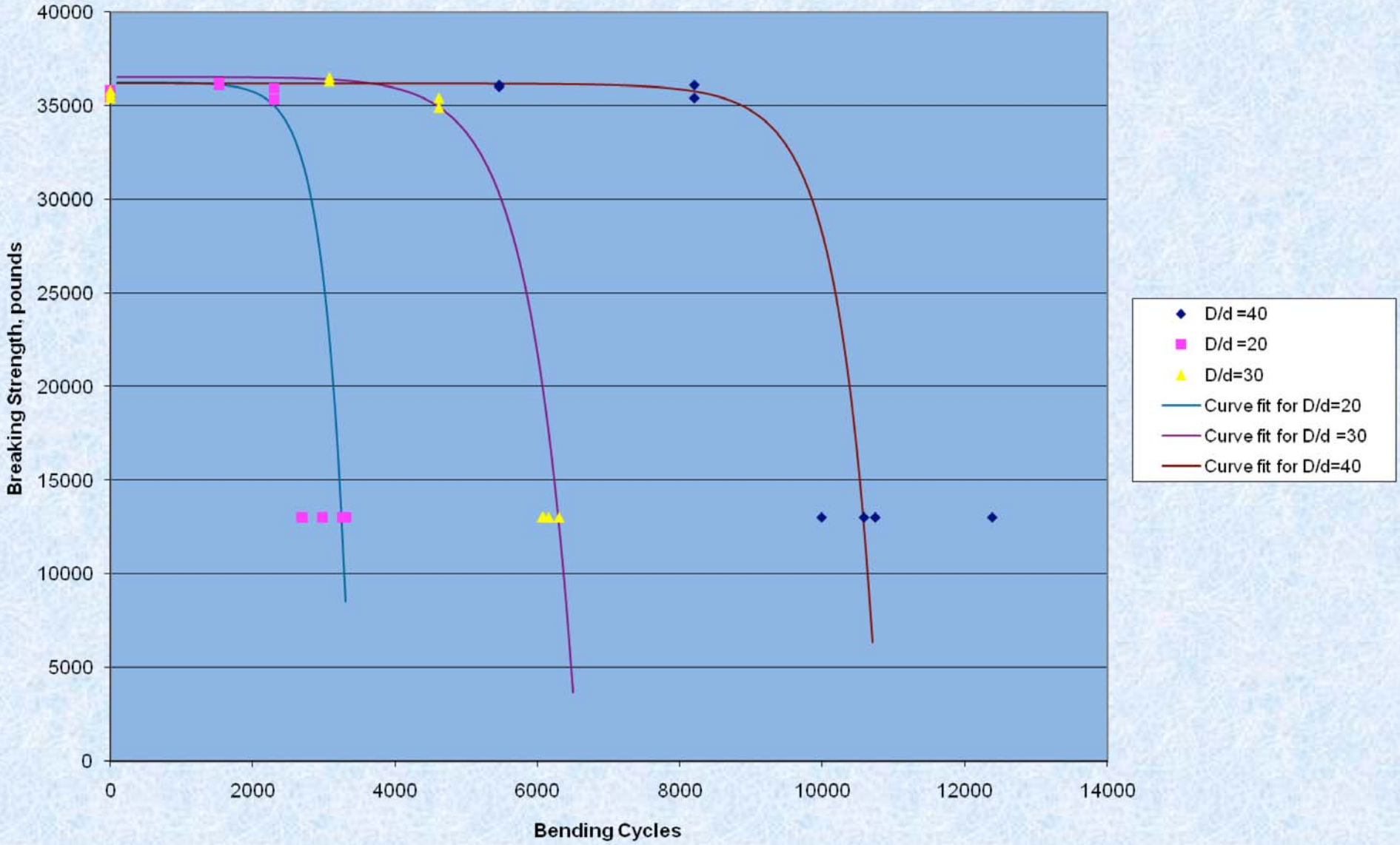
Effect of Decreasing D/d Ratio on Bending Fatigue Life

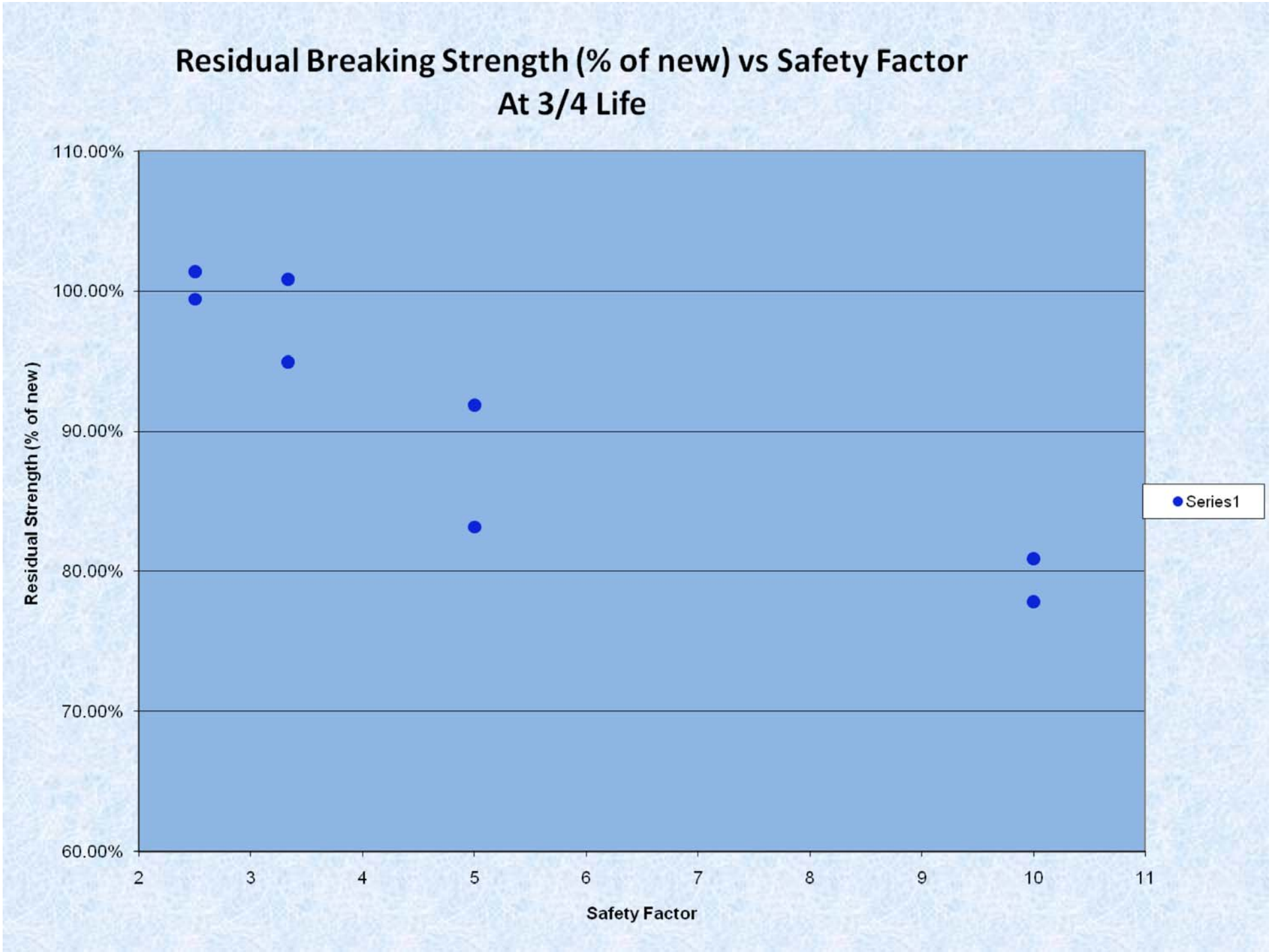
9/16-inch diameter 3x19 Wire Rope, Safety factor of 2.5, Residual Breaking Strength vs Bending Cycles for D/d = 40




9/16-inch diameter 3x19 Wire Rope,
Safety factor of 2.5,
Residual Breaking Strength vs Bending Cycles for D/d = 30 and 40
Breaking Strength, pounds
40000
35000
30000
25000
20000
15000
10000
5000
0
0
2000
4000
6000
8000
10000
12000
14000
Bending Cycles
D/d =40
D/d=30
Curve fit for D/d =30
Curve fit for D/d=40

9/16-inch diameter 3x19 Wire Rope,
Safety factor of 2.5,
Residual Breaking Strength vs Bending Cycles for D/d =20, 30, and 40




Residual Breaking Strength (% of new) vs Safety Factor
At 3/4 Life
110.00%
100.00%
90.00%
80.00%
70.00%
60.00%
Residual Strength (% of new)
2
3
4
5
6
7
8
9
10
11
Safety Factor
Series1

Life Factor

Life Factor = SF(D/d)

SF = Safety factor

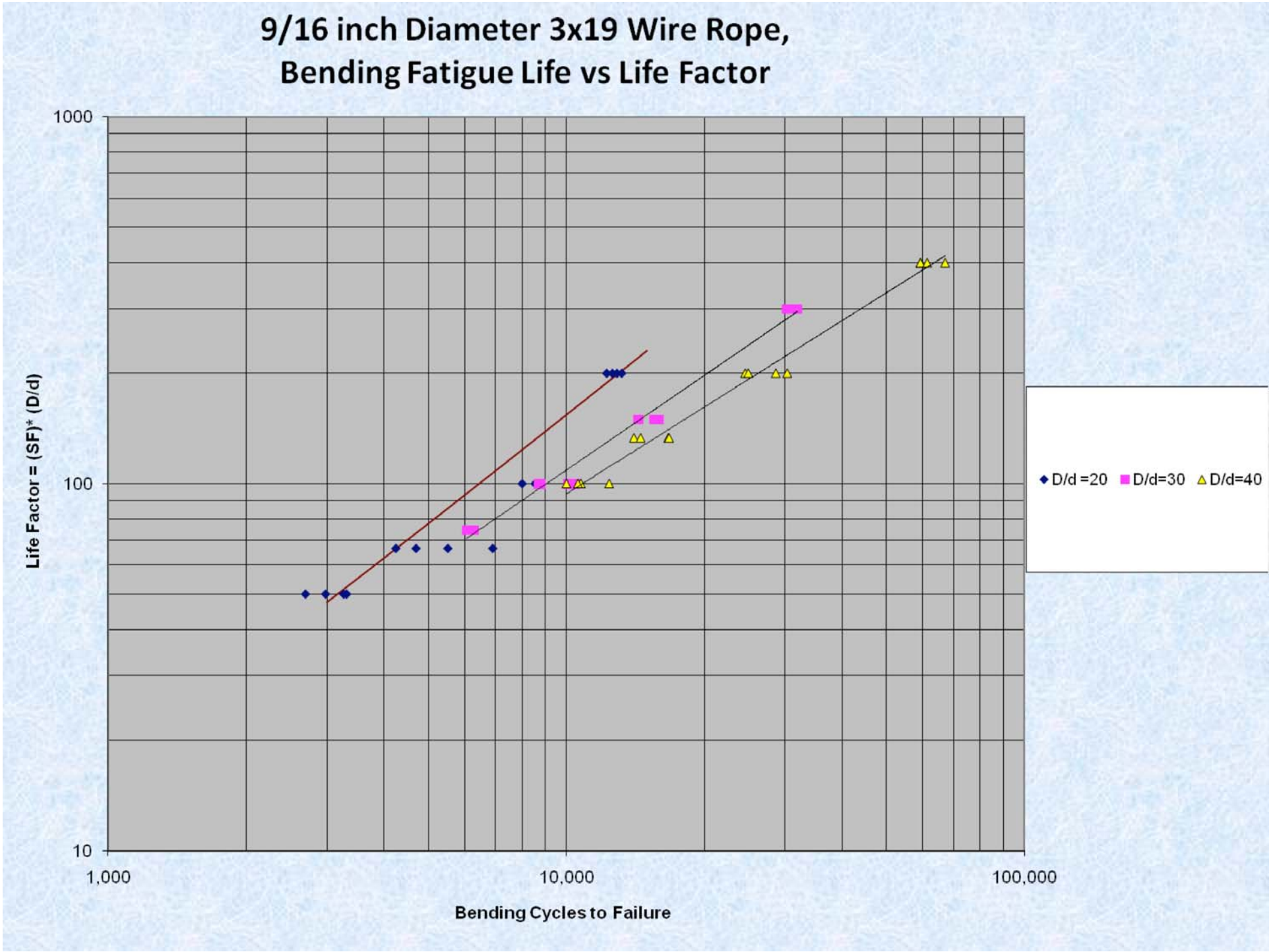
D= Sheave Diameter

d = rope diameter

Therefore:

Configurations resulting in large values for Life Factors would be associated with large safety factors and large sheave diameters which presumably results in a longer wire life.

Configurations with small Life Factors (Short life) would be associated with small safety factors and small sheave diameters.


9/16 inch Diameter 3x19 Wire Rope,
Bending Fatigue Life vs Life Factor
1000
100
10
Life Factor = (SF)* (D/d)
1,000
10,000
100,000
Bending Cycles to Failure
D/d =20
D/d=30
D/d=40

Summary

- Residual breaking strength of 3x19 rope drops abruptly after a certain number of accumulated bending cycles, especially when operating with small safety factors (high tensions).
- The rope may provide little evidence of impending fatigue failure, complicating the application of meaningful retirement criteria based on visual inspections.

Evaluating Wire Condition in the Field

Field Evaluation

Problem: Break tests are not usually conducted at sea. (not planned)

Problem: Break tests are not always a reliable indicator of rope condition.

Question: When cutting back to get to “good” wire, when do I know when I am there?

Question: Is there a way to make some evaluation of the condition of the wire in the field?

“e” KinK Testing

- Technique suggested by The Rochester Corp.
- Simple test of all the individual wires that make up a cable.
- Take an 18 inch length, hold each end and form it into a loop.
- Pull the loop taught, forming the shape of a small letter “e”.
- A wire break indicates that the material may be brittle and not fit for service.
- A failure rate of 30% or more is reason for taking the cable out of service.

e-Kink Testing

S.E.A. Corwith Cramer: .25 3 x 19 TB Wire

Test Date	Breaking Strength *(6,750 lbs. per manu.)*	*"e" Kink Test (% of metallic cross section area failed)*
9/24/2008	5,950 lbs.	77%
Cut back 600 meters		
10/6/2008	6020 lbs.	79%
10/6/2008	6,370 lbs.	76%
Wire used at sea and parted		
10/23/2008	5,870 lbs.	82%
Cut back 500 meters		
10/24/2008	6,030 lbs.	79%
Cut back additional 500 meters		
11/5/2008	5,750 lbs.	66%
12/19/2008	6,640 lbs.	59%
Replaced with new wire		

S.E.A. Robert C. Seamans: .25 3 x 19 TB Wire

Test Date	Breaking Strength	"e" Kink Test (% of
metallic	*(6,750 lbs. per manu.)*	*cross*
section area failed) Aug 08	5,260 lbs.	
62%		
Cut back 400 meters		
Aug 08	3,870 lbs.	77%
Cut back additional 600 meters		
9/16/08	7,420 lbs.	62%
9/16/08	7,600 lbs.	67%
Cut back additional 100 meters		
9/18/08	7,100 lbs.	41%
Wire off spooled from Seamans' working end at core of storage drum		
Non-working end tested		
10/8/08	6,120 lbs.	3%
New wire wound onto the Seamans		
10/8/08	7,270 lbs.	0%

Summary

- Just beginning to try to correlate wire condition with “e” kink test results.
- As part of our Research Vessel Testing program we are trying to do the test on all samples provided.
- Any information about wire performance in the field would be appreciated.

Questions?

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