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Tension Fatigue Testing

Tension fatigue occurs in steel wire or synthetic ropes subjected to fluctuating loads over an extended period of repeated cycles during use. It results in degradation of the material and a reduction in the strength of the rope. The impact of repeated tension cycles on the rope's strength is typically a function of the stress level exerted on the rope (represented by the load as a percentage of the rope's average break strength) as well as the material and construction characteristics of the rope.

In real-world applications, tension fatigue is usually only one of many contributing degradation mechanisms to which the rope is subjected. It is often difficult to represent "fatigue life" based purely on laboratory test results. However, lab testing is one way to indicate the relative difference in expected operating life between different rope products.

The most commonly utilized testing standard for comparing tension fatigue performance is the Thousand Cycle Load Limit (TCLL) test established in the *"OCIMF Guidelines for SPM Mooring Hawsers."* Samson uses this procedure to compare product performance amongst internal products as well as with ropes made by competitors. TCLL values express the maximum percentage of the breaking strength at which a rope can be cycle loaded 1,000 times. The object of the test is to measure the rope's resistance to tension-tension fatigue. A higher TCLL Value indicates higher resistance to cyclical tensile loading.

OVERVIEW

Ropes made from High Modulus Polyethylene (HMPE) have superior tension fatigue properties compared to ropes made from steel wire or other synthetic fibers (i.e. nylon, polyester, aramids, etc.), as shown in Table 1.

Table 1: TCLL VALUE OF VARIOUS MATERIALS
(condensed from DSM Dyneema chart)

UNIT	STEEL WIRE	ARAMID	POLYAMIDE	DYNEEMA
TCLL Value	60	73	55	90

A higher TCLL Value indicates higher resistance to cyclical tensile loading.

The testing summarized in this document is focused on HMPE-based ropes. The test included two samples of each rope type from three different manufactures, referred to here as AmSteel®-Blue and Saturn-12 (both Samson products), Product C, and Product D (from 2 different domestic manufacturers). All samples were 12-strand single braids, 3/8" (9 mm) nominal diameter, made from HMPE fiber (Samson AmSteel®-Blue and Saturn-12 are 100% Dyneema® HMPE fiber, Product C and D are 100% Spectra® HMPE fiber). Product D uses heat setting in post processing while Product C uses construction design characteristics that optimize break strength and keep stretch low. Samson's two products use a balanced construction that strives to achieve high strength and low stretch while maximizing fatigue life and abrasion resistance.

The effects of heat setting on HMPE rope is well documented (see Samson *Technical Bulletin: HMPE Rope – Effects of Post Production Processes*). HMPE ropes characteristically show an initial increase in strength as they are worked for the first 40% of their expected tension fatigue lifetime. Heat setting pushes the rope along the expected strength curve to the maximum strength the fiber will be expected to achieve before it is placed in service. The strength gain comes at the price of a significantly reduced fatigue lifetime.

The rope's construction design—twist levels and braid angles—also influences both strength, fatigue life and resistance to abrasion. (See Samson *Technical Bulletin: HMPE Rope: Design vs. Performance*). High strength can be achieved using a longer cycle length that results in a looser braid. Testing shows that it also results in lower tension fatigue resistance and lower abrasion resistance.

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TEST PROCEDURE

For these tests, the procedure for TCLL testing documented in the OCIMF (Oil Companies International Marine Forum) Guidelines was followed except that the rope was tested dry versus the recommended wet test. Dry was chosen as an acceptable method as long as all samples were subjected to the same conditions. Testing was performed at Samson's Innovation and Training Center testing laboratory in Ferndale, Washington.

The test procedure called for each sample to be subjected to 4 levels of cycling based on the rope's specified average break strength (ABS) — 50%, 60%, 70%, and 80% of ABS. The samples were subjected to 1,000 cycles to each of the first three loads (50%, 60%, 70%) and then, if they survived, 2,000 cycles at 80% of average break strength, totaling 5,000 cycles. The samples were then loaded to destruction, to measure the rope's residual strength.

For ropes that survived this cycling, a calculation was performed to determine a theoretical TCLL value. This value is intended to represent the load-level at which the rope would fail upon completing 1,000 cycles (see appendix A for relevant calculation and test method info).

TEST RESULTS

After completing 5,000 cycles, Samson's AmSteel®-Blue and Saturn-12 samples all broke above specified average strength. This indicates that there was minimal to no strength loss in the Samson ropes due to tension fatigue. Products C and D did not complete the testing. Product C averaged less than 4,400 total cycles, while product D averaged only 3,140 cycles. Additional results summarized in Table 2 and Figure 1 show the total cycles for each product.

The two Samson ropes – AmSteel®-Blue and Saturn-12 outperformed the two competitor's ropes because of the superior quality of the Dyneema® fiber, rope construction designed to maximize longevity, and because Samson ropes are not heat set. The effect of heat setting is illustrated in Figure 1.

PUTTING TCLL IN CONTEXT:

The prescribed TCLL test used is one way to indicate the relative difference in the expected operating life between different rope products. The results are based on the mean of the population for each rope type. The given number of cycles a rope will survive varies from sample to sample.

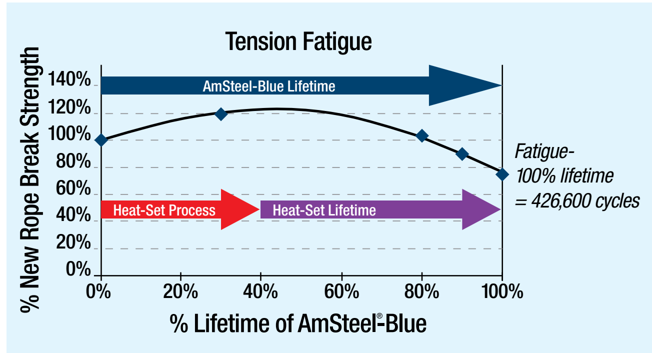
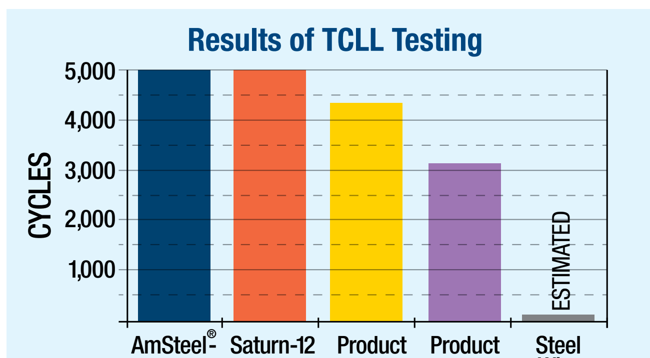


FIGURE 1 Fatigue lifetime comparison between AmSteel®-Blue and Post-Processed Rope
(refer to Samson Technical Bulletin:
HMPE Rope – Effects of Post Production Processes*)*

The calculated TCLL value does not differentiate between samples that may survive many more cycles beyond the 5,000 cycle test. Although it was chosen to test the samples dry, the impact of cyclic heat generation may have had a larger impact versus testing wet. The heat is generated by the cyclic loading in the test. Ropes in the field may rest relatively long periods of time, reducing the impact of heat generation. HMPE fiber strength is negatively affected by increasing temperature.



Both AmSteel®-Blue and Saturn-12 were the only ropes to complete all 5,000 cycles of the test and had residual strength indicating no strength loss due to tension fatigue.

Figure 2: **RESULTS OF TCLL TEST**
(refer to appendix for calculated cycles at 80% method)

APPENDIX

Equivalent Cycles at Higher Loads (OCIMF TCLL standard)

- 1,000 cycles at 50% = 251 cycles at 60%
- 1,000 cycles at 50% + 1,000 cycles at 60% = 215 cycles at 70%
- 1,000 cycles at 50% + 1,000 cycles at 60% + 1,000 cycles at 70% = 113 cycles at 80%

Determination of Thousand Cycle Load Level

- Calculation of load in which the sample would fail in a thousand cycles. The thousand cycle load level is expressed as a percentage of new (wet) rope break strength and calculated using the following equation:

WHERE:
TLL = *test load level, percentage of new (wet) rope break strength, the load level at which CTF was determined*

CTF = *cycles to failure at test load level*

6.91 = *natural logarithm of 1,000*

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