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Technical Bulletin 9A: Cyclic-Tension fatigue of Twin-Path® Slings

Cyclic-tension or tension-tension fatigue is the degradation of a sling from repeated loading and unloading. Fatigue is a major source of wear and is estimated to be the cause of up to 90% of failures in metal parts[1] and is a critical consideration when selecting a sling. There are two main factors that determine the tensile fatigue life of a lifting sling.

Material Fatigue

The first is the material's intrinsic fatigue properties. Absent of all other wear modes, most materials will eventually fail at a load below their original tensile strength if subjected to repeated cyclic loading. Different sling materials exhibit varying levels of resistance to cyclic tension, with high-tenacity synthetic fibers like K-Spec® Corn Yarn being generally superior to steel.

Internal Abrasion

The other factor is the degree of internal abrasion due to construction, friction and material type. In this case, as the strength members of the sling rub against each other they wear due to abrasion. These effects can be mitigated by choosing a sling material that has a low coefficient of friction and is resistant to abrasion as well as selecting a construction that minimizes cross-over between strength members. When there is cross-over, such as in a braided construction, each point acts in a sawing action leading to internal abrasion damage. As shown in Figure 1 K-Spec® Core Yarn has superior abrasion characteristics compared to other sling fibers.

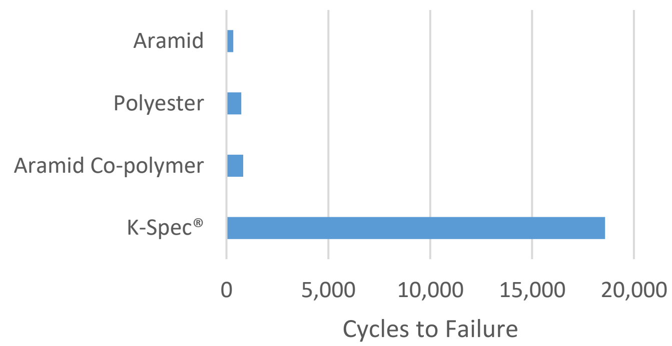

Figure 1- Yarn on Yarn Abrasion Results

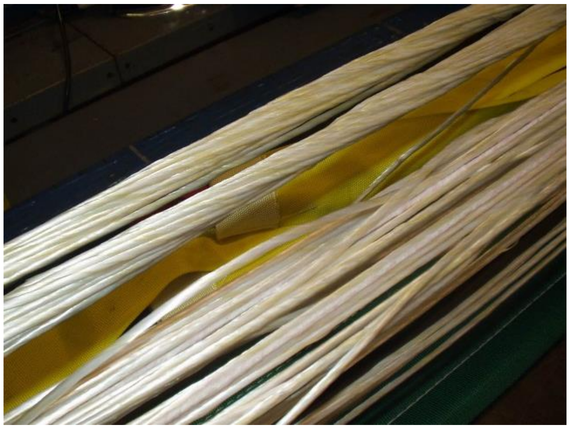

Figure 2- Rifled Core Yarns vs Parallel

Slingmax Design

Slingmax® Twin-Path® Extra Slings with K-Spec® Core Yarn are designed to minimize both of these modes of wear. The K-Spec® Core Yarn has been designed from materials with intrinsic resistance to cyclic-tension fatigue as well as a low coefficient of friction and high resistance to abrasion that combine to minimize wear due to internal abrasion. The Twin-Path design is optimized to achieve superior strength realization from the core yarn. The Rifled Cover® Technology design shown in Figure 2 increases the load sharing between the strands of K-Spec® Core Yarn compared to a parallel construction, without the damaging cross-over points found in braids.

Testing

To prove the performance of the Twin-Path® design, three Slingmax® TPXC2500 Twin-Path® Slings of 4 feet in length with a vertical load rating of 25,000 lb (5:1 design factor) were tested by cycling from 550 – 37,500 lb (250 – 17,010 kg) for 50,000 cycles. Each end of the sling was connected to the bow of a 13.5 ton anchor shackle for cyclic testing. After cycling one sling was then pulled to failure over the bow of a 30 ton anchor shackle. The bows of each shackle were ground to ensure a smooth loading surface.

Testing was performed on a MTS 225 ton horizontal tensile test machine. During the cycling, temperature was measured by inserting a thermometer into the center crease of the sling as close to the loading surface as possible. After 50,000 cycles, the slings were inspected for damage, each showed some hardening and wear at the contact point as shown in Figure 3, but all remained intact.

Figure 3- Loading Point After 50,000 Cycles

Results of the cycle test are listed in Tables 1 – 3 below. In each case, the Twin-Path® Slings with K-Spec® Core Yarn remained intact for the full 50,000 cycle test, and in cases of tests 1 and 2, the steel fixture actually had to be replaced due to failure during cycling. In the case of the sling that was pulled to failure, it still had 84% of its original minimum breaking strength, giving it a design factor of 4.2:1 after cycling to a 50% overload 50,000 times.

Table 1 - Sling 1 Results

Sling 1 – Serial Number C060619 (2 seconds per cycle)		
Number of Cycles	Cycle Time Elapsed	Result
5,459		Slightly warm to touch
11,340		Fixture at shackle bolt fractured
23,302	6 hr 39 min	Temperature 100.4°F
53,310		Test complete – no failure

Table 2 - Sling 2 Results

Sling 2 – Serial Number C060617 (4 seconds per cycle)		
Number of Cycles	Cycle Time Elapsed	Result
2,129	2 hr 22 min	Temperature 92.2°F
47,818		Fixture at shackle bolt fractured
51,728	4 hr 21 min	Temperature 91.6°F. Cyclic test complete
Break Test		105,100 lbs achieved (84% of original rating)

Table 3 - Sling 3 Results

Sling 3 – Serial Number C060616 (4 seconds per cycle)		
Number of Cycles	Cycle Time Elapsed	Result
3,775	4 hr 12 min	Temperature 93.2°F
6,510	7 hr 14 min	Temperature 93.6°F
23,337	25 hr 56 min	Temperature 90.6°F
28,180	31 hr 19 min	Temperature 93.4°F
50,000		Test complete – no failure

References

[1] Callister Jr., William D., 2003, *Materials Science and Engineering an Introduction*, John Wiley & Sons, Inc., New York, NY, Chap 8

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