Wire Rope Strength Testing vs. Discard Criteria — What Every Crane Operator Should Know

Static strength, fatigue strength, sample-location effects, and why the diameter rule is non-negotiable

Category: Wire Rope Inspection & Maintenance | **Applicable to:** Overhead, gantry, port, and metallurgical cranes (including ladle duty) | **Reference standards:** ISO 4309, ISO 2408, ISO 4308, EN 12385-4, GB/T 5972, GB/T 20118

Quick Answer

A used wire rope can measure a higher static breaking strength than a new rope of the same specification. This is a real phenomenon, explained by strain hardening, internal compaction of undamaged sections, and the fact that the catalog value is a minimum, not a typical strength. But this gain is measured on the best-preserved part of the rope — it does not represent the rope's actual condition in service.

Cranes do not fail by static tension. They fail by bending fatigue: progressive wire breaks, internal wear, core crushing. UTM breaking-force testing measures static strength, while the failure mode that matters is fatigue strength — two different properties. Once a rope reaches the diameter-based discard threshold, it must be replaced, regardless of any breaking-force test result.

1. The Observation

This FAQ addresses a question frequently raised by crane operators, maintenance teams, and industrial end users regarding wire rope service life. The typical observation is as follows:

- A wire rope on a crane reaches its diameter-based discard threshold after several months of service and is taken out of operation.
- A sample of the discarded rope is tested on a Universal Testing Machine (UTM) for static breaking force.
- The measured breaking force is higher than the catalog value of the new rope. For example, a φ28mm IWRC rope with a nominal MBF of 461 kN may test at around 499 kN after service — a gain of roughly 8%.

This result raises two natural questions:

1. Why does the breaking strength increase after extended service, instead of decreasing?

2. If the residual strength is still above nominal, can UTM testing be used in place of diameter measurement as the discard criterion?

Both questions have clear technical answers. The short version is: the strength increase is real but misleading, and UTM testing is not an appropriate discard criterion because it measures the wrong property — static strength rather than fatigue strength.

2. Why a Used Rope Can Test Stronger Than a New One

The effect is repeatable, well understood, and caused by four mechanisms that act together.

2.1 Strain hardening

High-carbon steel wires respond to cyclic tensile and bending loading by developing a higher dislocation density in the crystal lattice. Both yield and ultimate tensile strength of each individual wire rise. This is an intrinsic property of cold-drawn high-carbon steel, independent of rope construction. Typical contribution: +3% to +8%.

2.2 Bedding-in effect

A new rope leaves the factory with small geometric tolerances between wires and strands. In undamaged sections of the rope, wires settle into their most compact positions during early service, improving load sharing across the cross-section. Typical contribution: +1% to +4%.

2.3 Margin between nominal MBF and actual strength

The catalog value is the Minimum Breaking Force, defined in ISO 2408 and equivalent standards. By definition it is a minimum. As-manufactured ropes routinely test 3%–8% above MBF. Comparing a used-rope test result against the nominal value therefore mixes two different reference levels and overstates the apparent gain.

2.4 IWRC structural amplification

Independent Wire Rope Core constructions transmit higher internal contact pressure between wires than fibre-core ropes. Both strain hardening and bedding-in are more pronounced in IWRC ropes. Gains in the 8%–10% range are typical for heavy-duty IWRC installations.

Worked example: φ28mm IWRC rope at 461 kN nominal

A used-rope measurement of 499 kN against a 461 kN nominal represents a gain of approximately 8.2%. This is fully accounted for by strain hardening alone, without needing to invoke the bedding-in effect or the nominal MBF margin. The number is unremarkable from a material-science standpoint.

The critical caveat: this measurement reflects the best-preserved section of the rope. It does not represent the rope's condition along its full working length, and it does not address the failure mode that actually matters in crane service.

3. The Sample-Location Effect

This is one of the most important points in the analysis, and one that is frequently overlooked when UTM results are interpreted.

3.1 Where the sample comes from matters

When a UTM sample is cut from a discarded rope, it is almost always cut from a section that still looks reasonably intact. That section tends to be the portion of the rope that ran away from the high-wear zones — not the parts repeatedly passing over sheaves or through drum cross-over points, which are where damage actually concentrates.

A UTM sample taken from such an undamaged section will give a strength reading that combines strain hardening and bedding-in without the offsetting effect of the damage that triggered discard in the first place. The result is a high number that is mechanically correct but operationally misleading.

3.2 What happens if the sample is cut from the damaged section

If the UTM sample is deliberately cut from a section that has reached the diameter discard limit, the result is very different. The measured breaking force falls below the nominal MBF, typically by 10%–30%, and occasionally by more, depending on the severity of internal damage. The factors that cause this drop include:

- Reduced effective steel cross-section from combined external and internal wear.
- Broken internal wires that no longer contribute to load sharing.
- Core crushing that disrupts uniform load distribution among strands.
- Localized fatigue concentrations that seed crack propagation under static load.

3.3 Comparison

Sample Location	Undamaged Section	Damaged Section (at discard limit)
Typical UTM result vs.	Higher than nominal (+3% to	**Lower than nominal (–10% to –**

Sample Location	Undamaged Section	Damaged Section (at discard limit)
nominal MBF	+20%)	**30% or worse)**
Contributing factors	Strain hardening, bedding-in, nominal MBF being a minimum	Reduced steel cross-section from wear, broken internal wires, core crushing, localized fatigue
What the result reflects	Best-case residual strength, not the actual service condition	Actual remaining static capacity at the weakest section
Validity as a discard criterion	Misleading — suggests rope is stronger than it is in service	Confirms damage, but still insufficient alone — fatigue damage extends beyond the worst static spot

Key implication

The same rope can produce two very different UTM results depending on which section is tested. A high reading from an undamaged section does not mean the rope is safe. A low reading from a damaged section confirms that damage exists, but even this cannot be used as a discard criterion — because the damage that causes crane failures is fatigue-related and distributed along the full length of the rope, not concentrated at a single measurable breakpoint.

3.4 Why wear is never uniform along a wire rope

A running wire rope on a crane does not wear evenly along its length. Specific sections accumulate damage much faster than the rest, for reasons rooted in the mechanics of crane operation:

- Sections that repeatedly pass over sheaves experience concentrated bending cycles, which is the primary driver of fatigue wire breaks.
- Drum cross-over points — where the rope transitions between wrap layers — see high internal contact pressure and abrasion, causing localized diameter loss.
- Rope sections adjacent to the hook and the drum dead-end carry the full dynamic load and are subjected to the highest cyclic stress.
- The rope length that remains stationary on the drum during normal operation accumulates almost no damage, and this is typically where a UTM sample will appear in excellent condition.

This uneven damage distribution is the fundamental reason why the safety of a wire rope cannot be judged from a single sample, regardless of how rigorous the test equipment. The rope's service life is determined by its worst section, and that worst section must be found by full-length inspection, not by destructive testing of a fragment.

4. Static Strength vs. Fatigue Strength — The Core Distinction

This is the single most important concept in the entire discussion. Failing to distinguish between these two properties is what leads to the incorrect conclusion that a rope with good residual static strength is still safe to operate.

4.1 Two different properties

Static strength is the force the rope can withstand in a single, slow, static pull before rupture. This is what a UTM test measures. Fatigue strength is the rope's ability to survive repeated cyclic loading — bending over sheaves, winding onto drums, dynamic load variation — over thousands or millions of cycles.

These are related properties of the same piece of steel, but they are not the same property, and they degrade through different mechanisms:

Property	Static Strength	Fatigue Strength
Definition	Peak force the rope can withstand in a single static pull to failure	Ability of the rope to survive repeated cyclic loading over its service life
How it is measured	UTM breaking-force test on a short sample	Inferred from multi-criteria field inspection: diameter reduction, broken wire count, deformation, corrosion, wear
What degrades it	Severe wire damage, section loss, heat damage	Bending cycles over sheaves, internal wire fretting, core crushing, corrosion, loss of lubrication
Corresponding crane failure mode	Static tensile rupture (extremely rare in cranes)	**Bending fatigue with progressive wire breaks (the dominant failure mode in cranes)**

Property	Static Strength	Fatigue Strength
Correct use in the discard decision	Not used for discard; used for acceptance testing of new rope and post-service failure analysis	**Primary basis for discard, per ISO 4309 multi-criteria inspection**

4.2 Which one actually causes crane failures

In normal crane operation, the working load is well below the rope's breaking force — ISO 4308, EN 13001, and GB 3811 require safety factors typically between 4 and 8. A static tensile rupture during lifting is essentially a non-event in properly designed crane systems.

The failure mode that actually puts cranes out of service, and occasionally causes serious accidents, is bending fatigue. After enough cycles over sheaves and drums, wires begin breaking. These breaks accumulate, initially invisibly inside the rope, then visibly on the outside. Eventually a critical number of broken wires leads to sudden multi-wire failure, often during normal lifting and without warning.

Fatigue damage is precisely what a UTM breaking-force test cannot detect. A rope sample can retain excellent static strength while its fatigue life is nearly exhausted — the sample just has not yet seen the cycle that would have caused its first visible break in service.

The single most important sentence in this FAQ

UTM testing measures static strength. Cranes fail from fatigue strength. The two are not the same property, they degrade through different mechanisms, and a strong UTM result does not imply a rope that is safe to continue using.

5. Why UTM Testing Cannot Replace Diameter-Based Inspection

This point follows directly from Sections 3 and 4. UTM testing is a valid and useful tool, but it is not a discard tool.

5.1 UTM testing is destructive and local

A UTM test can only be performed on a short sample, typically cut from a rope that has already been removed from service. It measures one property at one point. A crane wire rope is a distributed system — its safety depends on the condition of every metre of its working length, not on the strength of a single sampled metre.

5.2 UTM testing measures the wrong property

Even if every metre of a rope could somehow be tested non-destructively in a UTM, the result would still not answer the question that matters for crane safety. Static strength does not predict remaining fatigue life. A rope at the end of its useful service life can produce perfectly acceptable UTM numbers and still be unsafe to operate.

5.3 UTM testing has three legitimate roles

3. **Incoming inspection of new ropes — verifying that as-delivered breaking force meets or exceeds the nominal MBF specified in the purchase contract.**
4. **Supplier quality audits — performed by the rope manufacturer or an independent laboratory as part of a quality-management system.**
5. **Post-service failure analysis — correlating residual strength with observed damage on a rope that has been taken out of service, to validate or refine inspection criteria.**

All three applications share a common characteristic: the rope being tested is either not yet in service or has already been removed from service. UTM testing is not used as the primary decision tool for whether a rope currently on a crane should continue operating.

6. The Correct Basis for Wire Rope Discard: ISO 4309 Multi-Criteria Inspection

ISO 4309 (Cranes — Wire ropes — Care and maintenance, inspection and discard) is the international standard governing wire rope discard decisions. GB/T 5972 is the equivalent Chinese standard. Both adopt the same fundamental approach: no single criterion is used in isolation; discard is triggered when any one of several in-service inspection criteria reaches its defined threshold.

Discard Criterion	What It Reflects
Diameter reduction	Internal wear, core compression, loss of lubricant, and internal wire breaks. A hard, measurable indicator of hidden damage not visible from the outside.
Visible broken wires	Accumulation of bending fatigue damage. Counted per outer strand, per reference length (typically 6d and 30d).
Internal broken wires	Fatigue damage hidden beneath the outer strands; especially relevant for IWRC ropes operating at low D/d ratios.

Discard Criterion	What It Reflects
Corrosion	Surface or internal oxidation that reduces wire cross-section and accelerates fatigue crack initiation.
Deformation (birdcage, kinks, waviness, core protrusion)	Structural damage that prevents uniform load distribution; often an immediate discard condition.
Heat damage	Discoloration or scaling from arc strikes, friction, or high ambient temperatures. Especially critical in metallurgical applications exposed to radiant heat.
External wear	Flattening of outer wires against sheaves, drums, and guides; directly reduces wire cross-section.

The rationale for this multi-criteria approach is precisely the point discussed in Section 4: any single indicator has blind spots. Diameter reduction captures internal damage but not external fatigue. Broken wire counts capture external fatigue but not core condition. Corrosion checks capture oxidation but not heat damage. Combined, these criteria cover the full range of failure modes that actually occur in crane service — failures that a static UTM test cannot detect.

7. Metallurgical Cranes — Heat and the Heavy-Duty Context

For cranes operating in metallurgical environments — ladle cranes, pot cranes, charging cranes, slab handling cranes — the considerations in Sections 1 through 6 still apply, but with additional stringency.

7.1 Why these applications are different

- **Duty classification**: metallurgical cranes typically operate at FEM classes M7 or M8, the heaviest duty bands, with high cycle counts and full-load operation as the norm, not the exception.
- **Heat exposure**: radiant heat from liquid steel, slag, and hot metal degrades rope lubricant rapidly and can cause direct heat damage to wires even without visible contact.
- **Environmental load**: mill scale, oxidized particulates, and chemically aggressive atmospheres accelerate corrosion and external wear.
- **Consequence of failure**: a rope failure during ladle, charging, or hot-metal handling carries risks far beyond a dropped load — liquid steel spillage, severe personal injury, equipment destruction, and extended production stoppage.

7.2 Implications for discard policy

In metallurgical applications, the diameter-based discard rule and the broader ISO 4309 multi-criteria framework should be treated as non-negotiable. Any proposal to extend rope service beyond the defined threshold — based on UTM test results, historical non-failure, or economic considerations — is inconsistent with the risk profile of these applications.

Additional criteria that warrant particular attention in metallurgical service:

- Any visible heat damage, discoloration, or scaling on the rope surface requires immediate discard, regardless of other indicators.
- Lubricant condition should be monitored continuously; a rope that has lost internal lubrication in a hot environment degrades internally much faster than surface inspection reveals.
- Inspection frequency should be shorter than for general-purpose cranes, and should increase further for cranes operating near capacity or through multiple shifts per day.

8. Inspection Scheduling and the Meaning of the Discard Threshold

A point that sometimes causes confusion: once a rope has reached the discard threshold, the question of inspection frequency no longer applies to that rope.

Inspection schedules — daily visual checks, weekly detailed inspections of high-wear zones, monthly full-length inspections, annual thorough examinations by a competent person — exist to detect when a rope has reached a discard condition. Once that condition is confirmed, the inspection framework has served its purpose. The correct next action is replacement, not a new inspection interval.

Asking whether a rope at the discard limit can be safely used for another day, another shift, or another hour is the wrong question. The discard threshold is defined so that ropes are replaced before the probability of failure becomes significant. A rope at the threshold has, by definition, exhausted the margin the standard reserves for safe operation. Any time beyond that point is taken from a reserve that was never intended to be spent.

The rule is simple

Inspection is how you find out when to replace the rope. UTM testing is how you verify quality at the two ends of a rope's life — incoming and post-service. Replacement, triggered by the discard threshold, is how you keep the crane safe.

None of these three activities can substitute for another.

9. Frequently Asked Questions

Q1. We tested a used rope and got a higher breaking force than the new-rope nominal. Is the test wrong?

No. The test is most likely correct. The increase is explained by strain hardening, internal compaction of undamaged sections, and the fact that the catalogue value is a minimum rather than a typical strength. Gains in the 5%–15% range are common. The sample was almost certainly cut from a well-preserved section of the rope, so the result reflects best-case residual strength, not the rope's actual service condition.

Q2. If we cut the sample from the damaged section instead, would the breaking strength be lower than the new rope?

Yes, and substantially so. Samples from sections that have reached the diameter discard limit typically test 10%–30% below nominal MBF, sometimes more. This is because the damaged section carries reduced effective cross-section from wear, internal broken wires, core crushing, and localized fatigue concentrations. The same rope can produce opposite-direction UTM results depending on which section is sampled — which is why any single UTM number, whether high or low, is not a valid discard criterion.

Q3. If the rope is still strong in UTM testing, why can't we keep using it?

Because static strength is not the failure mode. UTM testing measures static strength — the force required to pull a short sample apart in a single, slow loading event. Cranes fail by fatigue: repeated bending over sheaves and drums causes progressive wire breaks, internal wear, and core damage, leading eventually to sudden multi-wire failure during normal lifting. Fatigue strength and static strength are not the same property, and a rope with good residual static strength can have essentially zero remaining fatigue life.

Q4. Can we use UTM testing instead of diameter measurement to decide when to discard?

No. UTM testing is destructive, covers only a short sample, and measures the wrong property (static rather than fatigue). Industry standards — ISO 4309, GB/T 5972 — require multi-criteria in-service inspection: diameter, visible broken wires, internal broken wires, corrosion, deformation, heat damage, and external wear. This approach captures the full range of failure modes that actually occur in crane service, which no single test can.

Q5. We have been operating this way for years without an incident. Is the discard rule overly conservative?

No. Wire rope fatigue failure is statistical, not deterministic. A rope at the discard threshold has not reached the certain-failure point; it has reached the point where the probability of failure begins to rise meaningfully. Continued operation is not protected by the absence of past incidents — it is exposed to a rising probability that the standard was specifically written to prevent. The cost of a new rope is always less than the cost of an incident.

Q6. Once a rope reaches the discard threshold, how much longer can we safely use it?

This is the wrong question. The discard threshold is not the start of a new countdown — it is the end. The standard defines the threshold so that replacement happens before the probability of failure becomes significant. Asking how much longer a rope at the threshold can be used is asking how much of the reserved safety margin can be spent, which is inconsistent with the purpose of the standard. The correct answer is to replace the rope, not to define a new inspection interval.

Q7. Does rope construction (IWRC vs. fibre core) affect these conclusions?

The core conclusions apply to both. IWRC ropes show more pronounced strain-hardening and bedding-in effects, so the apparent strength gain in UTM testing tends to be larger. IWRC ropes also require more careful inspection for internal damage, since their stiffer structure can mask internal wear until it is advanced. The discard logic — multi-criteria inspection, diameter as a hard limit, UTM testing not used for discard — is the same for both.

Q8. How should inspection frequency be set?

Inspection frequency is set by the applicable standard and by the crane's duty classification, environmental severity, and operating intensity. For general-purpose cranes, daily visual checks by the operator combined with periodic detailed inspections by a qualified person are standard. For heavy-duty and metallurgical applications — ladle cranes, charging cranes, scrap handling, multi-shift operation — inspection intervals should be shorter, and any signs of heat damage or accelerated wear should trigger immediate replacement rather than extended observation.

10. References

- ISO 4309 — Cranes — Wire ropes — Care and maintenance, inspection and discard.
- ISO 2408 — Steel wire ropes — Requirements.
- ISO 4308 — Cranes and lifting appliances — Selection of wire ropes.
- EN 12385-4 — Steel wire ropes — Safety — Part 4: Stranded ropes for general lifting applications.
- GB/T 5972 — Wire ropes for lifting appliances — Code of practice for examination and discard.
- GB/T 20118 — Steel wire ropes for general purposes.
- EN 13001 — Cranes — General design.

Prepared by Kinocranes — Technical Support

This document is provided for general technical guidance. For rope selection, inspection intervals, and discard decisions on a specific installation, always follow the applicable national standard, the crane manufacturer's manual, and the judgment of a qualified rope inspector.

For project-specific advice, contact: info@kinocranes.com | www.kinocranes.com