04 / 2003

WIRE ROPE

05

Selection | Removal Criteria | Constructions | Specifications

UNIROPE® SLINGMAX WIRE ROPE & RIGGING PRODUCTS

Some Information every user should know about use and care of wire rope.
What follows is a brief outline of the basic information required to safely use wire rope.

1. Wire rope WILL FAIL IF WORN OUT, OVERLOADED, MISUSED, DAMAGED, or IMPROPERLY MAINTAINED.

2. In service, wire rope loses strength and work capability. Abuse and misuse increase the rate of loss.

3. The MINIMUM BREAKING STRENGTH of wire rope applies ONLY to a NEW, UNUSED rope.

4. The Minimum Breaking Strength should be considered the straight line pull with both rope ends fixed to prevent rotation, which will ACTUALLY BREAK a new, UNUSED, rope. The Minimum Breaking Strength of a rope should NEVER BE USED AS ITS WORKING LOAD.

5. To determine the working load of a wire rope, the MINIMUM or NOMINAL Breaking Strength MUST BE REDUCED by a DESIGN FACTOR (formerly called a Safety Factor). The Design Factor will vary depending upon the type of machine and installation, and the work performed. YOU must determine the applicable Design Factor for your use.

For example, a Design Factor of “5" means that the Minimum- or Nominal Breaking Strength of the wire rope must be DIVIDED BY FIVE to determine the maximum load that can be applied to the rope system.

Design Factors have been established by OSHA, by ANSI, by ASME and similar government and industrial organizations.

No wire rope should ever be installed or used without full knowledge and consideration of the Design Factor for the application.

6. WIRE ROPE WEARS OUT. The strength of a wire rope slightly increases after the break-in period, but will decrease over time. When approaching the finite fatigue life span, the breaking strength will sharply decrease. Never evaluate the remaining fatigue life of a wire rope by testing a portion of a rope to destruction only. An in depth rope inspection must be part of such evaluations.

7. NEVER overload a wire rope. This means NEVER use the rope where the load applied is greater than the working load determined by dividing the Minimum Breaking Strength of the rope by the appropriate Design Factor.

8. NEVER ‘SHOCK LOAD’ a wire rope. A sudden application of force or load can cause both visible external damage (e.g. birdcaging) and internal damage. There is no practical way to estimate the force applied by shock loading a rope. The sudden release of a load can also damage a wire rope.

9. Lubricant is applied to the wires and strands of a wire rope when manufactured. This lubricant is depleted when the rope is in service and should be replaced periodically.

10. Regular, periodic INSPECTIONS of the wire rope, and keeping of PERMANENT RECORDS SIGNED BY A QUALIFIED PERSON, are required by OSHA and other regulatory bodies for almost every rope installation. The purpose of inspection is to determine whether or not a wire rope may continue to be safely used on that application. Inspection criteria, including number and location of broken wires, wear and elongation, have been established by OSHA, ANSI, ASME and other organizations.

IF IN DOUBT, REPLACE THE ROPE.

Some inspection criteria on rope, sheaves and drums are outlined further in this brochure.

11. When a wire rope has been removed from service because it is no longer suitable, IT MUST NOT BE RE-USED ON ANOTHER APPLICATION.

12. Every wire rope user should be aware of the fact that each type of fitting attached to a wire rope has a specific efficiency rating which can reduce the working load of a rope assembly or rope system, and this must be given due consideration in determining the capacity of a wire rope system.

13. Some conditions that can lead to problems in a wire rope system include:

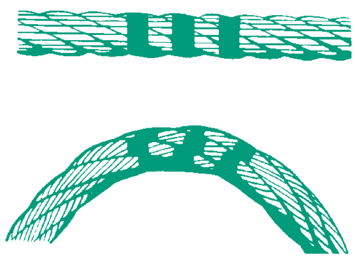
- Sheaves that are too small, worn or corrugated can cause damage to a wire rope.
- Broken wires mean a loss of strength.
- Kinks permanently damage a wire rope.
- Environmental factors such as corrosive conditions and heat can damage a wire rope.
- Lack of lubrication can significantly shorten the useful service life of a wire rope.
- Contact with electrical wire and the resulting arcing will damage a wire rope.

The above is based on the ‘Wire Rope Safety Bulletin’ published by the “WIRE ROPE TECHNICAL BOARD”.

Wire Rope is a Machine

A wire rope is a machine, by dictionary definition:"An assemblage of parts...that transmit forces, motion, and energy one to another in some predetermined manner and to some desired end."

A typical wire rope may contain hundreds of individual wires which are formed and fabricated to operate at close bearing tolerances one to another. When a wire rope bends, each of its many wires slides and adjusts in the bend to accommodate the difference in length between the inside and the outside bend. The sharper the bend, the greater the movement.



Every wire rope has three basic components:

(1) The wires which form the strands and collectively provide rope strength;
(2) The strands, which are helically around the core; and,
(3) The core, which forms a foundation for the strands.

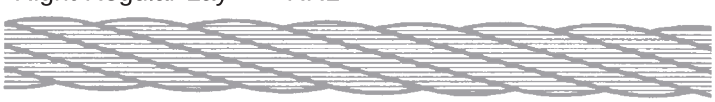
The core of wire rope is an Independent Wire Rope Core (IWRC), which is actually a rope in itself. The IWRC in Python rope provides between 10% and 50% (in non-rotating constructions) of the wire rope's strength.

The greatest difference in wire ropes are found in the number of strands, the construction of strands, the size of the core, and the lay direction of the strand versus the core.

The wires of wire rope are made of high-carbon steel. These carbon steel wires come in various grades. The term "Grade" is used to designate the strength of the wire rope. Wire ropes are usually made of Extra Improved Plow Steel (EIPS) or Extra Extra Improved Plow Steel (EEIPS)

One cannot determine the Grade of a wire rope by its feel or appearance. To properly evaluate a rope grade you must obtain the Grade from your employer or Unirope.

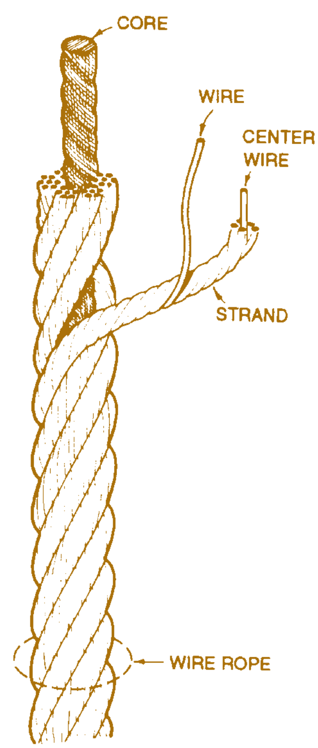
Right Regular Lay RRL



Left Regular Lay LRL

Right Lang Lay RLL

Left Lang Lay LLL



When to replace wire rope based on number of broken wires

Table A)

Standard	Equipment	Number of broken wires in Running Ropes: In one Rope Lay	Number of broken wires in Running Ropes: In one Strand	Number of broken wires in Standing Ropes: In one Strand	Number of broken wires in Standing Ropes: At End Connection
ASME/B30.2	Overhead & Gantry Cranes	12**	4	Not specified	
ASME/B30.4	Portal, Tower & Pillar Cranes	6**	3	3	2
ASME/B30.5	Crawler, Locomotive & Truck Cranes, Rotation Resistant Rope	Retirement criteria based on number of broken wires found in a length of wire rope equal to 6 times rope diameter- 2 broken wires maximum, and 30 times rope diameter- 4 broken wires maximum			
	Running Rope	6**	3	3	2
ASME/B30.6	Derricks	6**	3	3	2
ASME/B30.7	Base Mounted Drum Hoists	6**	3	3	2
ASME/B30.8	Floating Cranes & Derricks	6**	3	3	2
ASME/B30.16	Overhead Hoists	12**	4	Not specified	
ANSI/A10.4	Personnel Hoists	6**	3	2**	2
ANSI/A10.5	Material Hoists	6**	Not specified	Not specified	

** Also remove for 1 valley break (see next page for further information)

Rope Removal and possible Cause

Fault	Possible Cause
Accelerated Wear	Severe abrasion from being dragged over the ground or obstructions. Rope not suitable for application. Poorly aligned sheaves. Large fleet angle. Worn sheave with improper groove, size or shape. Sheaves and rollers have rough wear surface. Stiff or seized sheave bearings. High bearing and contact pressures. Sheaves/drum too small.
Rapid Appearance of Broken Wires	Rope not suitable for application. Reverse bends. Sheaves/drums too small. Overload and shock loads. Excessive rope vibration. Kinks that have formed and have been straightened out. Crushing and flattening of the rope. Sheave wobble.
Corrosion	Inadequate lubrication. Improper storage. Exposure to acids or alkalis.
Kinks	Improper installation. Improper handling. Slack rope pulled tight.
Excessive localized Wear	Drum crushing. Equalizer Sheave. Vibration.

Fault	Possible Cause
Stretch	Overload. Passed normal stretch and approaches failure.
Broken Wires near Fitting	Rope Vibration. Fittings get pulled too close to sheave or drum.
Sheaves/Drums Wear out	Material too soft
Pinching, Crushing, oval Shape	Sheaves grooves too small. Not following proper installation and maintenance procedure on multiple layer drums
Rope Unlays (Opens up)	Wrong rope construction. Rope end attached to swivel.
Reduction in Diameter	Broken core. Overload. Internal wear. Corrosion.
Bird Cage	Tight Sheaves. Rope is forced to rotate around its own axis. Shock loads. Improper Wedge Socket installation.
Core Protrusion	Shock loading. Disturbed rope lay. Rope unlays. Load spins and rotates rope around its own axis.

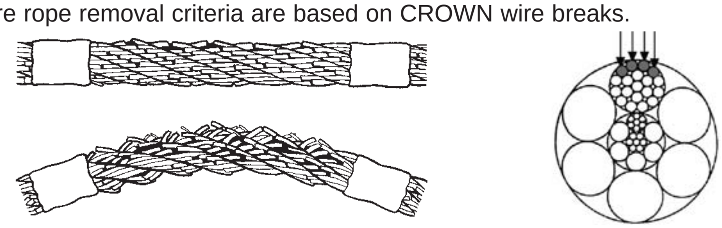
Wire Rope Inspection

An inspection should include verification that none of these removal criteria are met by checking for such things as:

- Surface wear, normal and unusual
- Broken wires: Number and location
- Reduction in diameter
- Rope stretch (elongation)
- Integrity of attachments
- Evidence of abuse or contact with other objects
- Heat damage
- Corrosion

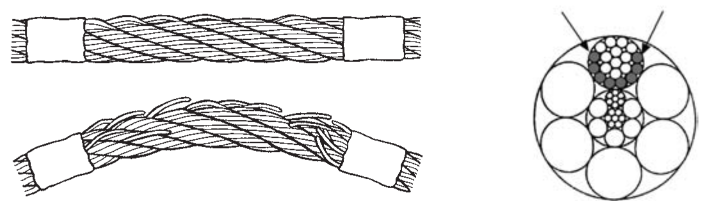
See Table A on the previous page for maximum allowable wire breaks causing discard of the rope.

Under normal operating conditions individual wires will break due to material FATIGUE. Such breaks are usually located at the CROWN of a strand. ALL wire rope removal criteria are based on CROWN wire breaks.

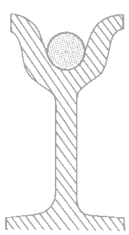


DANGER

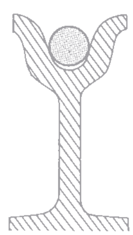
Remove the rope from service even if you find a SINGLE individual wire break which originates from inside of the rope. These so called VALLEY breaks have shown to be the cause for unexpected complete rope failures.



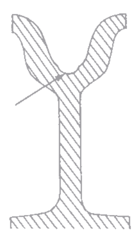
Inspection of Sheaves



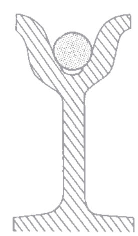
Sheave groove matches rope



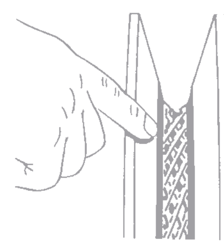
Sheave groove too small



Sheave groove worn out

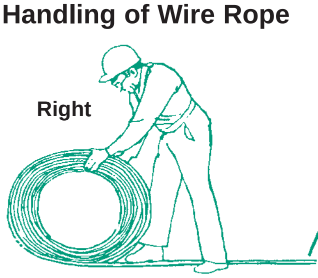


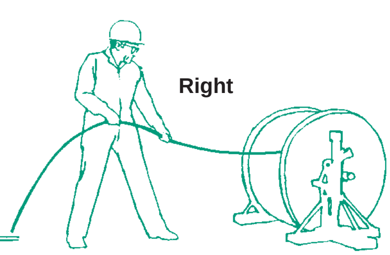
New rope will be damaged

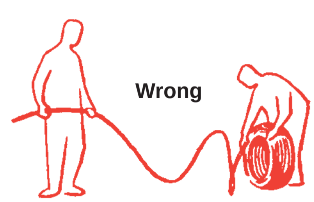


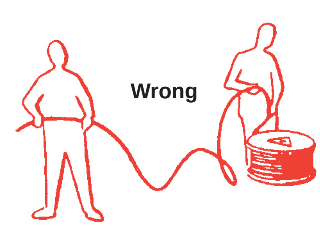
Check for worn and corrugated sheaves

Handling of Wire Rope









For a complete discussion on Handling, Installation, Inspection, and Maintenance of Wire Rope, please ask for our separate Catalogue

Measuring Wire Rope

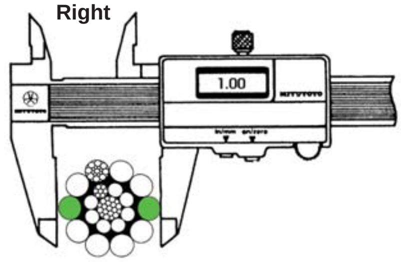
Design specification for wire rope are such that the diameter is slightly larger than the nominal size as shown in the catalogue. The allowable tolerances are:

≤ 1/8"	-0 / +8%
> 1/8" ≤ 3/16"	-0 / +7%
> 3/16"≤ 5/16"	-0 / +6%
> 5/16"	-0 / +5%

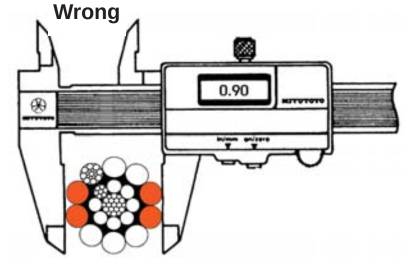
Python® wire rope is produced with an allowable oversize tolerance of only 4%, all others have an allowable 5% oversize tolerance.

When put into service the wire rope diameter slightly decreases when first loaded. A further reduction in wire rope diameter indicates wear, abrasion, or core deterioration.

Right



Wrong



Allowable Rope Oversize Tolerance

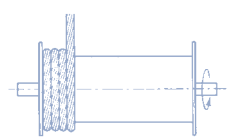
5% Diameter Tolerance			
Nominal Diameter inch	Maximum Diameter inch	Nominal Diameter mm	Maximum Diameter mm
3/8	.395	10	10.5
7/16	.46	11	11.5
1/2	.525	12	12.6
9/16	.590	14	14.7
5/8	.65	15	15.7
3/4	.79	16	16.8
7/8	.92	18	18.9
1	1.05	20	21
1-1/8	1.18	22	23.1
1-1/4	1.31	24	25.2
1-3/8	1.44	26	27.3
1-1/2	1.58	28	29.4
1-5/8	1.71	30	31.5
1-3/4	1.84	32	33.6
1-7/8	1.97	34	35.7
2	2.10	36	37.8

Wire Rope Lay Direction

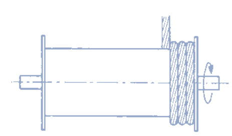
Be sure to use the correct rope lay direction for the drum. This applies to smooth, as well as to grooved drums.

In some applications it may be advisable to select the rope lay direction according to the most frequently used drums layers. If the first rope layer is used as a ‘guide layer’ only, it is advisable to select the rope lay direction according to the second layer.

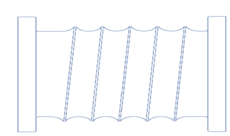
If you are in doubt about this issue, give us a call and we will be happy to assist you.



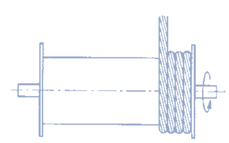
Overwind from left to right:
Use Right Hand Rope



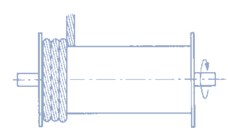
Underwind from right to left:
Use Right Hand Rope



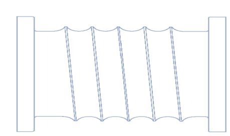
Left Hand Grooved:
Use Right Hand Rope



Overwind from right to left:
Use Left Hand Rope



Underwind from left to right:
Use Left Hand Rope



Right Hand Grooved:
Use Left Hand Rope

Strength

The breaking strength of wire rope can be increased in two ways: either by increasing the wire material TENSILE STRENGTH or by increasing the rope's FILL FACTOR.

TENSILE STRENGTH

The wires of wire rope are made of high-carbon steel. These carbon steel wires come in various grades. Wire ropes are usually made of Extra Improved Plow Steel (EIPS) or Extra Extra Improved Plow Steel (EEIPS) which roughly equivalents to a wire tensile strength of 1960N/mm^2 and 2160N/mm^2.

As one can see from the tables in this catalogue the difference in the rope's breaking strengths by increasing the material tensile strength is only about 10%.

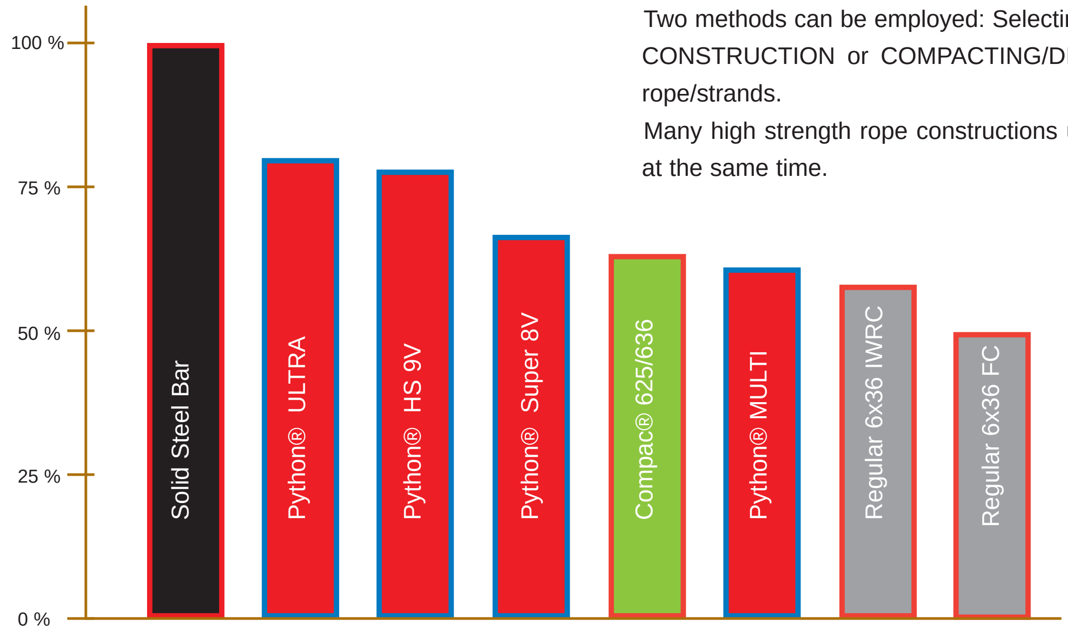
FILL FACTOR

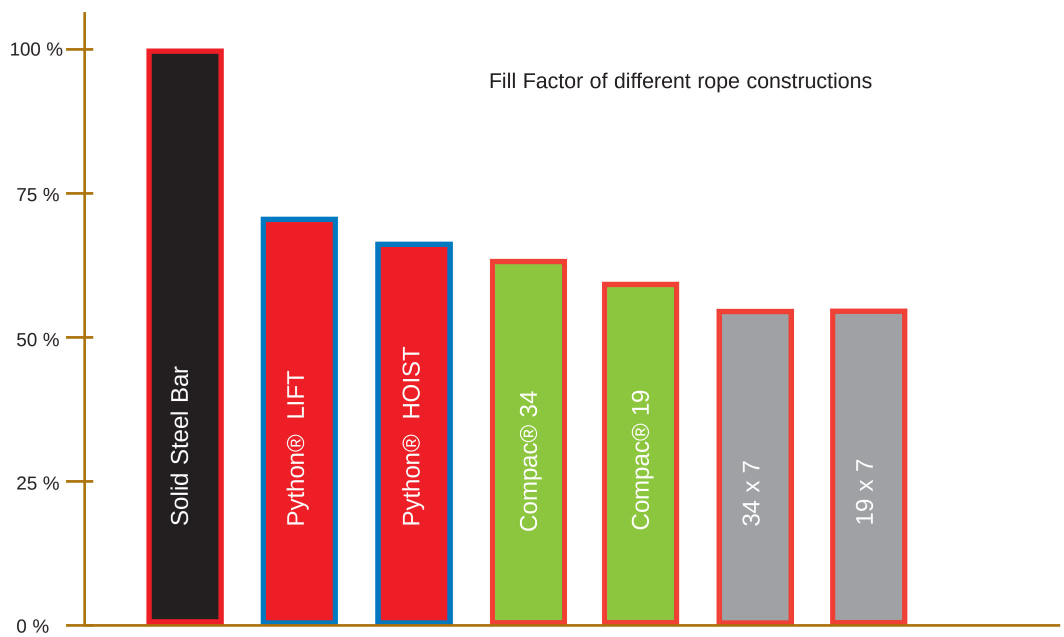
In order to further increase the breaking strength of wire rope one has to increase the rope's fill factor.

The fill factor measures the metallic cross section of a rope and compares this with the circumscribed area given by the rope diameter. Traditional rope constructions 'fill' the rope diameter only up to about 58% with steel. Python® and Compac® wire rope 'fill' the rope diameter up to 80% with steel. That is an metallic increase of about 38% which results in a similar increase in rope strength.

Two methods can be employed: Selecting a different rope CONSTRUCTION or COMPACTING/DIE DRAWING the rope/strands.

Many high strength rope constructions use both methods at the same time.





Fill Factor of different rope constructions

Strand- and Swage Compaction Process

Many of our wire ropes are manufactured using either the Strand Compaction- or the Swage Compaction process.
Here are the differences:

STRAND COMPACTION

This process is applied to the strands NOT to the rope. The ready made strands are forced through drawing dies which compress and shape the individual wires to have a flat outer surface. The advantages are

: increased strength
: less wire interlocking on multiple layer drums
: less contact pressures onto sheaves and drums

SWAGE COMPACTION

This process is usually applied to wire rope which is made using the double parallel manufacturing method, or where the rope core is plastic coated. This process is applied after the rope has been manufactured and compresses the entire rope circumference. Individual surface wires are shaped flat as well as closing strand gaps. The advantages are

: increased strength
: transforming the entire rope into a more ‘round’ shape
: less wire interlocking on multiple drums
: less contact pressure onto sheave and drums
: embedding strands into plastic coated cores
: achieve tighter diameter tolerances
: reduces constructional rope stretch to near zero


Standard strand wires


Strand Compacted


Swage Compacted

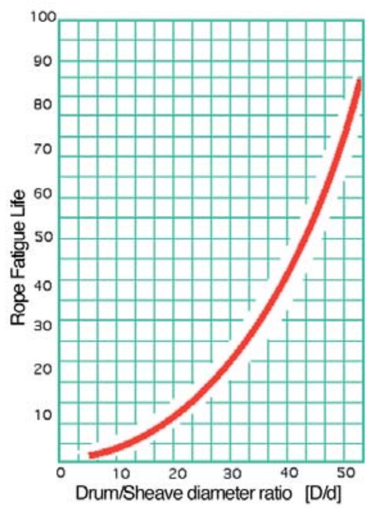
Bending Fatigue Resistance

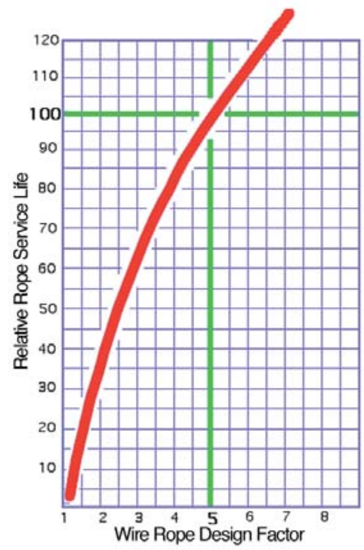
The ability of wire rope to withstand repeated bending work over sheaves and onto drums is also called the 'fatigue resistance'. This term describes the ultimate rope life based on the maximum mechanical fatigue resistance of the wire material used. This term does NOT describe the ability to withstand mechanical damages nor the crush resistance of a wire rope.

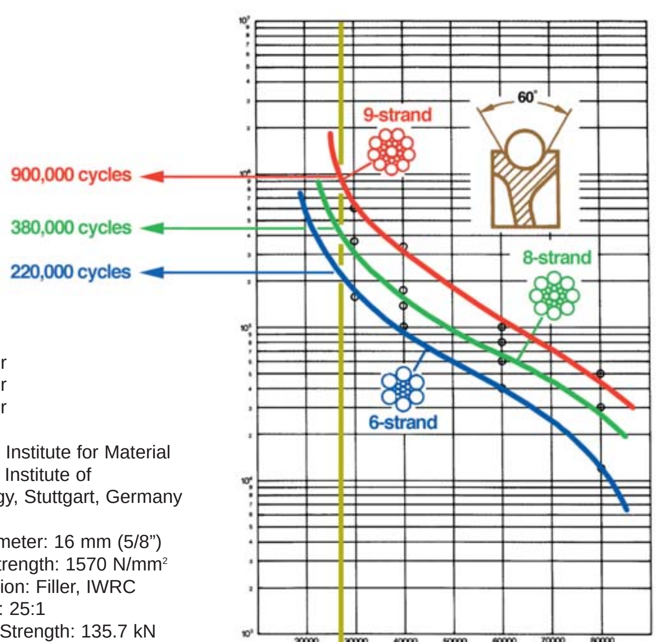
The fatigue resistance of a wire rope is not time- but cycle dependent. Bending fatigue is the ability to withstand repeated bending over sheaves and drums. The ability to withstand a certain number of bending cycles is linked to equipment related factors, such as

: diameter, shape, and groove dimensions of sheaves and drums
: the load the rope is subjected to
: the fluctuation of highest to light loads
: the line speed
: rapid acceleration and braking forces
: the rope construction

The larger the bending radii become, the higher is the expected fatigue life. Large drums and sheaves will reduce radial rope pressures. Reverse bends in the reeving system, especially within short distances, will have a major negative impact on rope life.







DF 5:1

6x19 Filler
8x19 Filler
9x19 Filler

Research Institute for Material Handling, Institute of Technology, Stuttgart, Germany

Rope diameter: 16 mm (5/8")
Tensile Strength: 1570 N/mm²
Construction: Filler, IWRC
D/d Ratio: 25:1
Breaking Strength: 135.7 kN

Rope Service Life

Many years of monitoring rope performance in the field together with scientific research at Universities and Technical Institutes have led to the recognition that the number of outer strands in a rope is a very significant factor influencing rope service life.

The number of outer strands determines the contact area between the rope and sheave groove. If this area is increased the points of contact are multiplied and abrasive wear of rope and sheave is reduced. At the same time lateral notching stresses between strands and wires are reduced, resulting in increased fatigue life.

Extensive test programs at the University of Stuttgart, Germany, have proven conclusively that bending fatigue of wire rope improves with an increasing number of outer strands.

Based on this research we have developed high performance wire rope with 8-, 9-, and 10 outer strands.

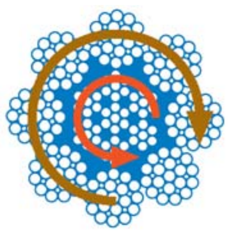
Rotation Resistant and Non-Rotating Wire Rope

When loaded, every wire rope will develop torque; that is it has the tendency to

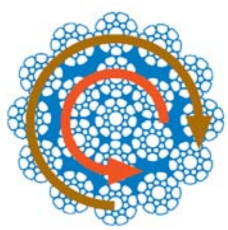
: unlay itself unless both rope ends are secured against rotation.

: cause a lower sheave block to rotate and to spin the line parts together.

Rotation resistant ropes can be divided into 3 categories:



Spin-Resistant, 2 layer
(8 to 10 outer strands)



Rotation Resistant, 2 layer
(11 to 13 outer strands)

Non-Rotating, 3 layer
(11 or more outer strands)

Example of a 2-layer rotation resistant construction with 12 outer strands. (19x7)

The characteristic of these wire ropes are that the outer layer is twisted in the opposite direction of their inner layers. The sometimes confusing issue is that many 8-, 9- and 10 strand constructions are 2-layer types but their inner strands are NOT twisted in the opposite direction and therefore these rope are NOT spin-resistant; plus, for the untrained eye these ropes look very much alike their spin-resistant variants. These and regular 6-strand ropes will spin violently and unlay themselves when loaded, with one rope end allowed to spin freely. They may also develop a significant drop in breaking strength and an even larger drop in their fatigue life characteristic when used with one end allowed to rotate.

As already mentioned, to achieve any degree of resisting the tendency of a rope to spin and unlay under load all such rope types (other than 4-strand ones) are constructed with 2 or more layers of opposite twisted strands.

2-layer ropes have a larger tendency to rotate than 3-layer ones (e.g. class 34x7). Furthermore, 2-layer spin-resistant and rotation resistant ropes will develop only about 55% to 75% of their breaking strength when one end is allowed to rotate freely. This number increases to between 95% to 100% for 3-layer non-rotating ropes.

Another important issue is that 2-layer rotation resistant and 2-layer spin-resistant rope types have shown to break up from the inside. The 8 (e.g. 8x25 spin-resistant) or 12 outer strands (19x7, 19x19, Compac®19) are not able to evenly distribute the radial forces and because of the inherent internal strand cross overs (which make the rope spin- or rotation resistant) the resultant severe notching stresses cause the rope core to break up premature (unless the core is plastic coated, e.g. Python® Multi). Unexpected and sudden rope failures may be the result. Moreover, 2-layer spin-resistant or rotation resistant ropes satisfy only low to moderate rotational resistance demands.

3-layer rope constructions (e.g. class 34x7) have many more outer strands which can much better distribute the radial pressures onto the reverse lay inner strands. These ropes should be selected for larger mobile- and ALL tower cranes.

Sheaves and Drums

The performance of all wire ropes is depended on the good condition and sufficient dimensions of sheaves and drums. Too small sheaves and drums will reduce the service life of a rope. This is more a question of 'performance' rather than 'safety'. The following table is based upon recommendations by the Wire Rope Technical Board:

Construction	Suggested D/d ratio
19x7 / 18x7	34
6x26 WS	30
6x25 Filler, 6x31 WS, Compac® 626	26
6x36 WS, Compac® 636Python® HS9, Ultra	23
8x25, Python® Super 8, Multi	20
Compac® 19 & 34, Python® Lift and Hoist	20
8x36 WS	18

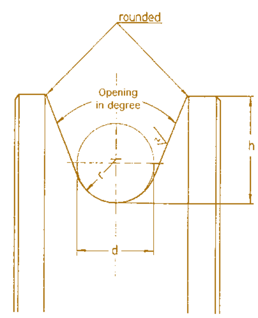
Sheave opening angle should be 35˚ to 45˚ for applications with fleet angles ≤ 1.5˚, for larger fleet angles use 60˚ opening.

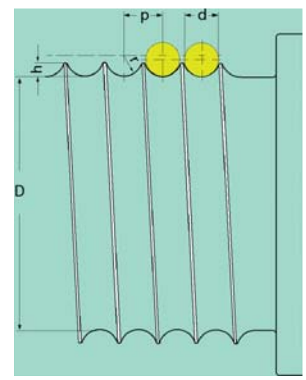
Maximum rope fleet angle for general purpose ropes should not exceed 4˚, for non-rotating/rotation resistant types and Python® HS-9 and Ultra the fleet angle should not exceed 1.5˚

Recommended Sheave and Drum Contours:
Groove radii minimum: 0.53 to .535x d for new rope
Groove radii maximum: 0.55 to 0.56x d
Sheave Groove depth: 1.5 x d

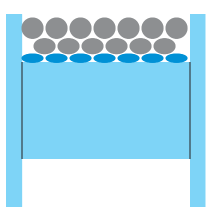
Drum Pitch for SINGLE layer minimum: 2.065 x groove radii
Drum Pitch for SINGLE layer maximum: 2.18 x groove radii
Drum groove depth: minimum ≥ 0.375x d for helical grooved

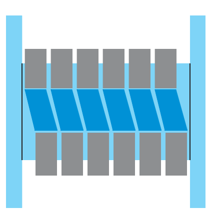
Hardness: As wire rope has a hardness of about 50-55RC we recommend that the hardness of sheaves and drums is at least 35 RC, better is 40-45 RC





Sheaves and Drums

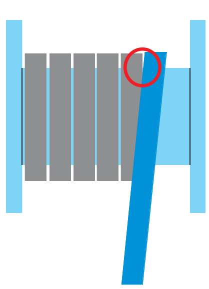




Multi-layer drum systems should use Compac® or type 'V' Python® rope constructions having a steel core. The higher fill factor of such rope constructions will offer a greater resistance to crushing and flattening than conventional rope types. This is particularly important for boom hoist ropes on lattice boom cranes at the cross over point from one rope winding to the next.

Cranes equipped with multi-layer drum systems which require rotation-resistant or non-rotating rope are best served with Python® or Python Compac® rope constructions (Python Compac® 18 and 34, Python® LIFT) as these have a smooth outer surface allowing the rope to better 'glide' from one winding into the next.

To further reduce drum crushing have the first rope layer wound onto the drum with about 5-10% of the WLL and avoid that this first layer unspools and re-spools without tension. This would cause a 'soft' bottom layer which will flatten rather quickly.



Compac® and Python® ropes also help reduce strand interlocking which normally occurs at adjacent rope wraps. This is caused by too large of fleet angles as well as is the cause of multiple layer windings on smooth (ungrooved) drums.

Compac® and Python® ropes have a smooth and very round outer rope surface which helps to minimize abrasive wear due to strand-to-strand contacts.

For further information please refer to our Catalogue 'Handling Procedures'.