1. Hoist Ropes

Various constructions of ropes may be used for hoisting, the final choice usually being decided upon economic grounds. What may be a satisfactory life on a shallow high frequency hoist, may be completely uneconomic on a deep low frequency installation, and therefore the rope designs as well as their sizes must be considered.

1.1 Drum Hoists

6 Stranded Ropes – both round and triangular strand – are satisfactory for all depths of shafts, although perhaps best suited for those up to 1000m in depth with fixed guides. They are not suitable for shafts deeper than 600m with rope guides, as their natural tendency to twist causes the conveyance to turn.

As a rough guide to the construction of the rope, the ratio of drum or sheave diameter to outer wire diameter should be between 1000 and 1500:1, although if abrasion is severe this can be reduced slightly at the expense of a lower fatigue life.

For maximum resistance to wear and crossover damage the use of Lang's lay is recommended.

Multi-Strand Rotation Resistant Ropes – are now used on permanent drum hoist installations, except where multi layer coiling is employed, due to their relatively low resistance to compressive forces. Certain constructions are suitable for sinking purposes.

Multi-strand ropes with Dyformed (compacted) strands have increased resistance to crushing over ropes with conventional strands.

Locked Coil Ropes – have gained in popularity and are extensively used throughout the UK. They can be used to advantage on any depth of shaft with either fixed or rope guides. As they are virtually non-rotating under normal loading conditions they are considered to be the best rope to operate in shafts deeper than 700 metres equipped with rope guides.

The cross section is extremely compact and as a result such ropes can withstand very high radial and compressive forces This property coupled with their smooth outer surface enables them to be used to advantage on multi layer coiling installations.

Because of their compact cross section, it is desirable that the drum or sheave diameter to rope diameter ratio should be in the region of 100 to 120:1 for satisfactory service life on main shaft winders. Ratios as low as 50:1 can be tolerated on small ropes in shallow shafts, staple shafts and sinking stage winders.

1.2 Friction or Koepe Hoists

6 Stranded Ropes – are suitable to depths of 1000 metres. Beyond that the torque in these ropes can result in premature torsional fatigue of the wires. Triangular strands are more usual due to the lower contact pressures on the friction linings although Lang's lay equal laid round strand ropes are quite suitable for shallow shafts. Round strand ropes with Dyformed (compacted) strands are becoming more popular as they offer higher breaking loads, increased fatigue life and reduced contact pressures over ropes with conventional strands.

With rope guided shafts, alternate left and right hand lay ropes are employed to prevent conveyance twist.

Tread pressures with stranded ropes are limited to 17.5 kgf/cm2 (1.72Mpa) to avoid excessive wear of the friction linings.

Multi-Strand Rotation Resistant Ropes – can be usefully employed at all depths of shaft and generally satisfactory lives are obtained. Earlier designs of the ropes were subject to severe internal cross-cutting, although modern designs incorporating Dyformed (compacted) strands and plastic enhancement coupled with modern design and manufacturing techniques most of these problems have been eliminated.

Tread pressure limits are similar to those of 6 stranded ropes.

Locked Coil Ropes – are widely used on this type of hoist particularly in the UK. The advantages offered by ropes of this construction make them particularly suited for this type of hoist especially if rope guides are employed.

Due to the large smooth surface area of locked coil ropes, tread pressures of up to 28.0 kgf/cm2 (2.75Mpa) can be tolerated. The limit is used to minimise friction liner wear, the rope being able to withstand much higher pressures.

1.3 Recommended Rope Construction for various winder applications

Type of winder application	Rope Construction
Small drum hoist operation at less than 2.5m/s in a vertical shaft with fixed guides	6x19(9/9/) FC Langs Lay Full Locked Coil
Small Drum hoist operating in a vertical shaft with rope guides	Multi-strand Rotation Resistant Full Locked Coil
Large drum hoist operating in a vertical shaft with fixed guides	Compound Triangular Strand Langs Lay Full Locked Coil Dyform 6R Ordinary Lay
Large drum hoist operating in a vertical shaft with rope guides	Multi-strand Rotation Resistant Full Locked Coil
Blair multi-rope hoist	Compound Triangular Strand Langs Lay Full Locked Coil
Friction hoist operating to a depth of 500m	6 strand Ordinary Lay Compound Triangular Strand Langs Lay Multi-strand Rotation Resistant Full Locked Coil Dyform 6R Ordinary Lay
Friction hoist operating to a depth between 500m and 1000m	6 Strand Ordinary Lay Compound Triangular Strand Langs Lay Multi-strand Rotation Resistant Full Locked Coil Dyform 6R Ordinary Lay
Friction hoist operating to depth between 500m and 1000m	Multi-strand Rotation Resistant Full Locked Coil Compound TS Langs Lay Dyform 6R Ordinary Lay
Friction Hoists above 1000m	Locked Coil Winding Ropes Multi Strand Rotation Resistant Dyform 6R Ordinary Lay Compound Triangular Strand Langs Lay
Sinking stage winder	Multi-strand Rotation Resistant Full Locked Coil Alternate Lay Triangular Strand Langs Lay
Kibble winder	Multi-strand Rotation Resistant Full Locked Coil
Tail/Balance rope	Multi-strand Rotation Resistant Superflex Flat rope

2. Sinking Ropes

Kibble Ropes – Ropes used for these duties must be rotation resistant, to prevent excessive spin of the kibble or bucket in the shaft.

Providing the hoist equipment is suitable, flexible full locked coil ropes meet these requirements admirably, and have been used successfully for many years. Where very small diameter sinking drums and sheaves are employed, or where a sheave is fitted above the kibble to enable two parts of rope to support the load, multi-strand rotation resistant ropes are suitable.

Bridon's dedicated Mining Department will be pleased to discuss and recommend the best ropes construction for optimum performance on your kibble winder.

Stage Ropes – There are several methods of suspending the sinking stage or platform and this can govern the choice of rope construction.

Stage ropes are normally required to act has guide ropes for the kibble so resistance to wear is a necessary characteristic. In addition a good resistance to crushing on the multi-layer drum coiling is required.

Full locked coil ropes offer excellent performance on the correct design of equipment.

Where smaller drums and sheaves are employed multi-strand rotation resistant ropes with relatively large outer wires or triangular strands with equal numbers of left and right hand lay can be used. With triangular strand ropes however, problems can be experienced with controlling the turn if slack rope conditions occur.

Bridon's dedicated Mining Department will be pleased to discuss and recommend the best ropes construction for optimum performance on your stage winder.

Under normal circumstances it is recommended that ropes for both applications, but in particular stage ropes, should be manufactured from galvanised material. However, where higher tensile grades of wire are required galvanised material is not always available. In these cases it is strongly recommended that the ropes are regularly cleaned and re-lubricated with emphasis on the evaluation of corrosion during examination.

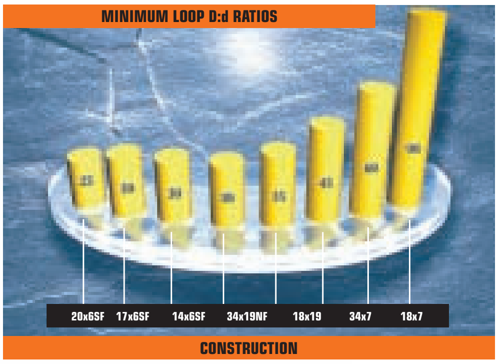
3. Balance Ropes

Generally balance ropes are required to have the flexibility to suit the particular cage centres, adequate rotation resistant properties combined with good resistance to wear and corrosion. Bridon's range of multi-strand rotation resistant ropes has the capability to meet the needs for all balance rope applications.

Bridon's Superflex balance ropes were developed for installations where maximum flexibility is required combined with optimum resistance to wear and corrosion. The range of ropes is almost completely non-rotating. As a result there is no torsional effect either at the terminal ends or at the loop and therefore the onset of fatigue at these points is almost entirely eliminated.

Where maximum flexibility is not required alternative constructions are available to best suit the specific winding conditions and give optimum economic service life.

The graph below gives the minimum recommended loop diameter to rope diameter ratio for various constructions.



For advice on the best rope for your installations contact Bridon's dedicated Mining Department.

4. Guide and Rubbing Ropes

Bridon's Tiger Brand range of guide and rubbing ropes are normally constructed of central king wire, covered by one or two layers of round wires which are closed in a final layer of half lock and round wires. The precise construction depending upon the diameter and the tensile grade of wires used to meet the breaking force requirement. Bridon's CAD rope design system ensures that the largest possible outer half lock and round wires are used to give maximum resistance to wear and corrosion.

The choice of size and breaking load depends upon the local regulations for factor of safety and the tensioning required. A typical arrangement is a factor of safety of 5:1 at the point of suspension with the guides tensioned on the basis of 3000kg plus 500kg for each 100m of shaft depth. The tensions are normally varied in the range plus or minus 10% to limit harmonic vibration.

In wet and corrosive shafts the use of galvanised material is recommended.

Types of tensioning arrangement, terminations and methods of installation are many and varied and Bridon's dedicated Mining Department will be please to give advise on these aspects along with types of layouts, methods of lubrication, inspection procedures and maintenance.

5. Haulage Ropes

The modern rope haulage system is an integral part of the system for both the transportation of men and the supply of materials to the mine face.

Haulage systems fall into 3 main categories
Endless
Direct
Main and Tail

Bridon's Tiger Brand range has the rope to suit your system.

In general, haulage ropes are required to have excellent resistance to wear and in some instances corrosion. To achieve this they tend to be of the more simple construction with fewer larger outer wires. These can be single layer round strand construction or triangular strand construction. On the majority of systems where the length of travel is high and the frequency of cycle is small, fatigue is generally not a critical deteriorating factor.

5.1 Single Construction

Round Strand
6x7(6/1) Fibre Core Langs lay is recommended to maximise the resistance to wear.

Triangular Strand
6x8TS, 6x9TS, 6x10TS.

However, when travel distances become shorter and the cycle frequency is higher then fatigue can become a factor dictating rope removal, particularly when drive wheels, drums and sheaves are smaller. To combat this more complex (compound constructions) with smaller outer wires can be used.

5.2 Compound Construction

Round Strand
6x19S, 6x26WS, 6x25F, 6x36WS.

Triangular Strand
6x22TS, 6x23TS, 6x25TS, 6x28TS.

Where wet and corrosive conditions exist the use of galvanised ropes, man made fibre cores or a combination of both is recommended.

On certain installations where resistance to crushing is required then the use of ropes with steel IWRC cores should be considered.

On endless systems ropes with special preforming are supplied to facilitate long splicing.

The performance of round strand ropes can be enhanced by the use of Dyformed strands. Dyform ropes offer the following improvements:-

- Higher breaking loads
- Improved fatigue life
- Increased resistance to crushing
- Reduced interference on drums and Clifton (surge) wheels

Bristar Cores offer the following improvements:-

- Reduced stretch
- Increased fatigue life
- Increased dimension stability (diameter retention)

Contact our dedicated Mining Department for advise on the best construction for your haulage application.

6. Conveyor Drive Ropes

Bridon has had a close working relationship with the O.E.M. of cable driven conveyors for many years. This has resulted in Bridon being the major supplier of cable belt driving ropes world wide. Extensive research and development has resulted in Bridons Tiger Brand range of driving ropes such that Bridon can offer rope solutions to give optimum lowest cost conveying of material.

The Tiger Brand range offers the following rope options:-

Conventional Driving Ropes
6x19S, 6x26WS, 6x25F, 6x31WS, 6x36WS.

The type of construction used depends upon the diameter, stress levels, the type of conveyor and it's layout.

Dyform Driving Ropes
6x19S Dyform, 6x26WS Dyform, 6x31WS Dyform, 6x36WS Dyform.

Dyform Driving Ropes offer the following advantages:-

- Higher breaking forces
- Increased fatigue life
- Increased resistance to wear
- Reduced line stand pulley wear during the early part of service life

Driving ropes are generally supplied in galvanised material although ropes manufactured from bright wire are available. They are produced under the highest quality system from high specification wire and cores specially designed and manufactured for use on rope driven conveyors. All ropes have specific strand preformation to facilitate long splicing and maximisation of splice life.

In both conventional and Dyform drive ropes alternative cores and manufacturing lubrication are available to best suit your conveyor conditions to ensure maximum economic operating performance. These include the following:-

- Man made fibre cores for use in wet conditions
- Bristar cores offering lower stretch, increased fatigue life and improve diameter retention
- Special lubrication, both manufacturing and service, to ensure maximum life in severe corrosive conditions

Zebra Drive Ropes

Joint development with rope driven conveyor manufacturers and operators has resulted in Bridon's Zebra range of conveyor drive ropes.

Extensive laboratory and on site testing has shown the following advantages of Zebra over conventional and Dyform drive ropes:

- Increased fatigue life. In excess of 10 times conventional cables in laboratory tests
- Equivalent or increased breaking loads
- Reduced stretch both constructional and elastic
- Superior diameter retention
- Smooth outer surface
- Reduced tread pressures
- Superior resistance to internal corrosion

These improvements in physical properties have realised the following proven cost saving advantages:

- Zebra can be retro fitted to existing conveyors at minimal cost
- Reduced line pulley performance
- Reduced steel terminal pulley and surge/Koepe lining maintenance
- Reduced vibration and noise
- Extended rope life
- Extended splice life

For an assessment of potential cost saving on your conveyor contact Bridon's directly.

Bridon's commitment to lowest cost conveying doesn't stop there. On long conveyors splicing and splice maintenance can be both inconvenient and costly. Bridon's unique Service Department can provide expert engineers to install, splice, inspect and maintain your drive cables. Driving ropes are a major cost component part of the conveyor. LOOK AFTER THEM !

In addition Bridon recognised the implications in down time and cost for splicing on long conveyors with numerous splices. To minimise splicing and splice repairs Bridon increased their production capacity from piece weights of 60 tons to piece weights of approximately 135 tons. If you think longer ropes can assist in reducing operating costs please contact our Mining Department who will be pleased to discuss the possibilities.

7. Properties of Extension of Steel Wire Ropes

Any assembly of steel wires spun into a helical formation, either as a strand or wire rope, when subjected to a tensile load, can extend in three separate phases, depending on the magnitude of the applied load.

There are also other factors which produce rope extension which are very small and can normally be ignored.

Phase 1 - Initial or Permanent Constructional Extension

At the commencement of loading a new rope, extension is created by the bedding down of the assembled wires with a corresponding reduction in overall diameter. This reduction in diameter creates an excess length of wire which is accommodated by a lengthening of the helical lay. When sufficiently large bearing areas have been generated on adjacent wires to withstand the circumferential compressive loads, this mechanically created extension ceases and the extension in Phase 2 commences. The Initial Extension of any rope cannot be accurately determined by calculation and has no elastic properties.

The practical value of this characteristic depends upon many factors, the most important being the type and construction of rope, the range of loads and the number and frequency of the cycles of operation. It is not possible to quote exact values for the various constructions of rope in use, but the following approximate values may be employed to give reasonably accurate results.

	% of rope length	
	Fibre Core	Steel Core
Lightly loaded Factor of safety about 8:1	0.25	0.125
Normally loaded Factor of safety about 5:1	0.50	0.25
Heavily loaded Factor of safety about 3:1	0.75	0.50
Heavily loaded with many bends and/or deflections	Up to 2.00	Up to 1.00

The above figures are for guidance purposes. More precise figures are available upon request.

Locked Coil Hoist Ropes

Immediate permanent extension	0.08
Additional initial extension	0.08
Gradual permanent extension	0.08
Total extension approx.	0.25

Phase 2 - Elastic Extension

Following Phase 1, the rope extends in a manner which complies approximately with Hookes Law (stress is proportional to strain) until the Limit of Proportionality or Elastic Limit is reached.

It is important to note that wire ropes do not possess a Young's Modulus of Elasticity, but an 'apparent' Modulus of Elasticity can be determined between two fixed loads.

The Modulus of Elasticity also varies with different rope constructions, but generally increases as the cross-sectional area of steel increases. By using the values given, it is possible to make a reasonable estimate of elastic extension, but if greater accuracy is required it is advisable to carry out a modulus test on an actual sample of the rope. As rope users will find it difficult to calculate the actual metallic steel area , the values normally quoted are based on the circumscribed rope area (area of a circle, related to the nominal diameter of the rope).

Elastic Extension $= \frac{WL}{EA}$ *(mm)*

W = load applied (kgs)
L = rope length (mm)
E = elastic modulus (kg/mm²)
A = circumscribed rope area (mm²)

Phase 3 - Permanent Extension

The permanent, non-elastic extension of the steel caused by tensile loads exceeding the yield point of the material.

If the load exceeds the Limit of Proportionality, the rate of extension will accelerate as the load is increased, until a loading is reached at which continuous extension will commence, causing the wire rope to fracture without any further increase of load.

Thermal Expansion and Contraction

The coefficient of linear expansion ($\propto$) of steel wire rope is 0.0000125 = (12.5×10^{-6}) per °C and therefore the change in length of 1 metre of rope produced by a temperature change of t °C would be;

Change in length $\Delta l = \propto l_o t$ *where*

$\propto$ *= coefficient of linear expansion*
l_o *= original length of rope (m)*
t *= temperature change (°C)*

The change will be an increase in length if the temperature rises and a decrease in length if the temperature falls.

Extension due to Rotation

The elongation caused by a free rope end being allowed to rotate.

Extension due to Wear

The elongation due to inter-wire wear which reduces the cross-sectional area of steel and produces extra constructional extension.

Example: What will be the total elongation of a 200 metre length of 28mm diameter Tiger 6R wire rope at a tension of 10 tonnesf (tf) and with an increase in temperature of 20°C.

Permanent Constructional Extension = 0.25% of rope length = 500mm

Elastic Extension $= \frac{WL}{EA} = \frac{10000 \times 200\,000}{6000 \times 615.8} = 540mm$

Thermal Expansion $= \Delta l = \propto l_o t = 0.0000125 \times 200 \times 20 = 50mm$

Therefore total extension = 500 + 540 + 50 = 1090mm

8. Pressures between Ropes and Sheaves or Drums

In addition to bending stresses experienced by wire ropes operating over sheaves or pulleys, ropes are also subjected to radial pressure as they make contact with the sheave. This pressure sets up shearing stresses in the wires, distorts the rope's structure and affects the rate of wear of the sheave grooves. When a rope passes over a sheave, the load on the sheave results from the tension in the rope and the angle of rope contact. It is independent of the diameter of the sheave.

$$\textit{Load on bearing} = 2T \sin \frac{\theta}{2}$$

Assuming that the rope is supported in a well fitting groove, then the pressure between the rope and the groove is dependent upon the rope tension and diameter but is independent of the arc of contact.

$$\textit{Pressure, } P = \frac{2T}{Dd}$$

P = pressure (kg/cm²)
T = rope tension (kg)
D = diameter of sheave or drum (cm)
d = diameter of rope (cm)

Maximum Permissible Pressures

Number of outer wires in strands	Groove material		
	Cast iron kgf/cm²	Low carbon cast steel kgf/cm²	11 to 13% Mn steel or equivalent alloy steels kgf/cm²
5 - 8 Ordinary lay	20	40	105
5 - 8 Lang's lay	25	45	120
9 - 13 Ordinary lay	35	60	175
9 - 13 Lang's lay	40	70	200
14 - 18 Ordinary lay	42	75	210
14 - 18 Lang's lay	47	85	240
Triangular strand	55	100	280

It should be emphasised that this method of estimation of pressure assumes that the area of contact of the rope in the groove is on the full rope diameter, whereas in fact only the crowns of the outer wires are actually in contact with the groove. The local pressures at these contact points may be as high as 5 times those calculated and therefore the values given above cannot be related to the compressive strength of the groove material.

If the pressure is high, the compressive strength of the material in the groove may be insufficient to prevent excessive wear and indentation and this in turn will damage the outer wires of the rope and effect its working life. As with bending stresses, stresses due to radial pressure increase as the diameter of the sheave decreases. Although high bending stresses generally call for the use of flexible rope constructions having relatively small diameter outer wires, these have less ability to withstand heavy pressures than do the larger wires in the less flexible constructions. If the calculated pressures are too high for the particular material chosen for the sheaves or drums or indentations are being experienced, consideration should be given to an increase in sheave or drum diameter. Such a modification would not only reduce the groove pressure, but would also improve the fatigue life of the rope.

The pressure of the rope against the sheave also cause distortion and flattening of the rope structure. This can be controlled by using sheaves with the correct groove profile which, for general purposes, suggests an optimum groove radius of nominal rope radius +10%. The profile at the bottom of the groove should be circular over an angle of approximately 120°, and the angle of flare between the sides of the sheave should be approximately 52°.

Hardness of Rope Wire

Rope grade	Approximate Equivalent	Approximate Hardness	
Min. Tensile Strength	API 9A Grade	Brinel	Rockwell 'C'
2160N / mm²	EEIPS	480 / 500	52
1960N / mm²	EIPS	470 / 480	51
1770N / mm²	IPS	445 / 470	49
1570N / mm²	PS	405 / 425	45

Suggested pulley hardness: 250-300 Brinell for Mn steel or equivalent alloy steel.

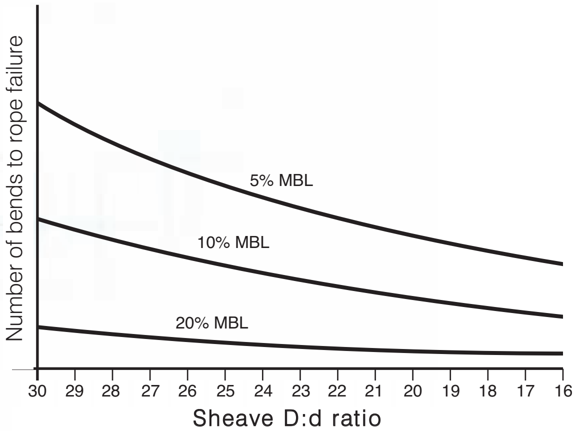
If the calculated pressure is too high for the particular material chosen for the pulley or drum, consideration should be given to increase in pulley or drum diameter. Such a modification would not only reduce the groove pressure, but would also improve the fatigue life of the rope by reducing the bending stresses imposed.

9. Bend Fatigue

Bend fatigue testing of ropes usually consists of cycling a length of rope over a sheave while the rope is under a constant tension and as part of its ongoing development programme Bridon has tested literally thousands of ropes in this manner over the years on its in-house own design bend testing equipment.

Through this work, Bridon has been able to compare the effects of rope construction, tensile strength, lay direction, sheave size, groove profile and tensile loading on bend fatigue performance under ideal operating conditions. At the same time it has been possible to compare rope life to discard criteria (e.g. as laid down in ISO 4309) with that to complete failure of the rope, i.e. to the point where the rope has been unable to sustain the load any longer. As part of the exercise, it has also been possible to establish the residual breaking strength of the rope at discard level of deterioration.

Effects of D:d Ratio and loading on fatigue life - Typical example Dyform 6

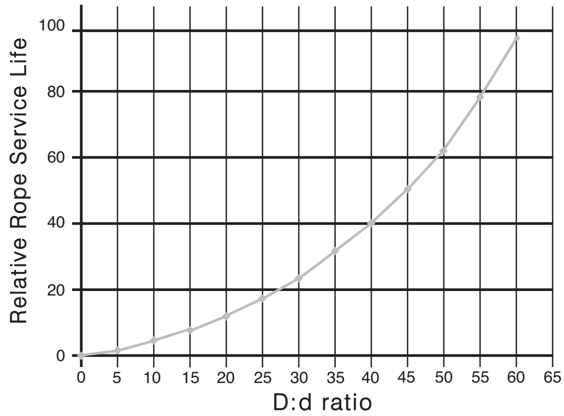


What needs to be recognised, however, is that very few ropes operate under these controlled operating conditions, making it very difficult to use this base information when attempting to predict rope life under other conditions. Other influencing factors, such as dynamic loading, differential loads in the cycle, fleet angle, reeving arrangement, type of coiling on the drum, change in rope direction, sheave alignment, sheave size and groove profile, can have an equally dramatic effect on rope performance.

However, the benefit of such testing can be particularly helpful to the rope manufacturer when developing new or improving existing products.

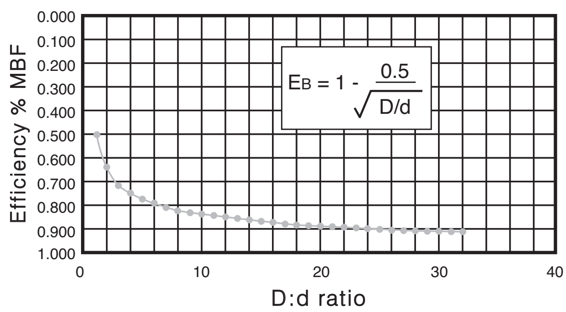
If designers or operators of equipment are seeking optimum rope performance or regard bending fatigue life as a key factor in the operation of equipment, such information can be provided by Bridon for guidance purposes.

Service life curve for various D:d ratios



When considering the use of a steel wire rope around a minimum D:d ratio, it is generally accepted that at below 4:1 the effect on the strength of the rope needs to be considered. Permanent distortions within the rope will occur when using ratios of 10:1 and less and that a minimum ratio of 16:1 be used for a rope operating around sheaves.

Approximate loss in breaking strength due to bending

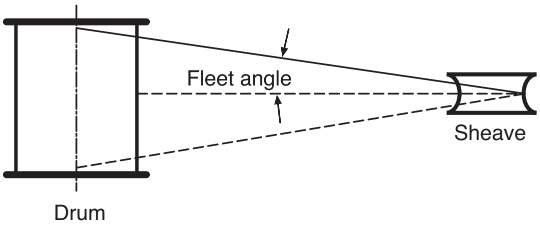


10. Fleet Angle

Of all the factors which have some influence on the winding of a rope on a smooth drum, the fleet angle, arguably, has the greatest effect.

Fleet angle is usually defined as the included angle between two lines, one which extends from a fixed sheave to the flange of a drum and the other which extends from the same fixed sheave to the drum in a line perpendicular to the axis of the drum. (See illustration).

Illustration of Fleet Angle



If the drum incorporates helical grooving, the helix angle of the groove needs to be added or subtracted from the fleet angle as described above to determine the actual fleet angle experienced by the rope.

At the drum

When spooling rope onto a drum it is generally recommended that the fleet angle is limited to between 0.5° and 2.5°. If the fleet angle is too small, i.e. less than 0.5°, the rope will tend to pile up at the drum flange and fail to return across the drum. In this situation, the problem may be alleviated by introducing a 'kicker' device or by increasing the fleet angle through the introduction of a sheave or spooling mechanism.

If the rope is allowed to pile up it will eventually roll away from the flange creating a shock load in both the rope and the structure of the mechanism, an undesirable and unsafe operating condition.

Excessively high fleet angles will return the rope across the drum prematurely, creating gaps between wraps of rope close to the flanges as well as increasing the pressure on the rope at the cross-over positions.

Even where helical grooving is provided, large fleet angles will inevitably result in localised areas of mechanical damage as the wires 'pluck' against each other. This is often referred to as 'interference' but the amount can be reduced by selecting a Langs lay rope if the reeving allows. The "interference" effect can also be reduced by employing a Dyform rope which offers a much smoother exterior surface than conventional rope constructions.

Floating sheaves or specially designed fleet angle compensating devices may also be employed to reduce the fleet angle effect.

At the sheave

Where a fleet angle exists as the rope enters a sheave, it initially makes contact with the sheave flange. As the rope continues to pass through the sheave it moves down the flange until it sits in the bottom of the groove. In doing so, even when under tension, the rope will actually roll as well as slide. As a result of the rolling action the rope is twisted, i.e. turn is induced into or out of the rope, either shortening or lengthening the lay length of the outer layer of strands. As the fleet angle increases so does the amount of twist.

To reduce the amount of twist to an acceptable level the fleet angle should be limited to 2.5° for grooved drums and 1.5° for plain drums and when using rotation-resistant low rotation and parallel-closed ropes the fleet angle should be limited to 1.5°.

However, for some applications it is recognised that for practical reasons it is not always possible to comply with these general recommendations, in which case the rope life could be affected.

11. Rope Torque

The problem of torsional instability in hoist ropes would not exist if the ropes could be perfectly torque balanced under load. The torque generated in a wire rope under load is usually directly related to the applied load by a constant 'torque factor'. For a given rope construction the torque factor can be expressed as a proportion of the rope diameter and this has been done below..

Variation with rope construction is relatively small and hence the scope for dramatically changing the stability of a hoisting system is limited. Nevertheless the choice of the correct rope can have a deciding influence, especially in systems which are operating close to the critical limit. It should be noted that the rope torque referred to here is purely that due to tensile loading. No account is taken of the possible residual torque due, for example, to rope manufacture or installation procedures.

Torsional Stability

The torque factors quoted on page 34 are approximate maximum values for the particular constructions. To calculate the torque value for a particular rope size multiply by the nominal rope diameter. Example: for 20mm dia. Tiger 34LR 34x7 Class at 20% of minimum breaking force:-

Torque value = torque factor x rope dia.
= 0.8% x 20mm
= 0.16mm

Rope Torque

To calculate the torque generated in a particular rope when subjected to a tensile load, multiply the load by the torque value and combine the units.

Example: for 20mm dia. Tiger 34LR 34x7 Class at 6000 kg f load

Torque generated = torque value x load
= 0.16 . 6000
= 960 kgf.mm

Bending Loads

As the rope is bent over the headsheave or drum, an additional force is induced into the steel which must be added to the static and dynamic tensions to obtain the total force imposed. There are many methods of calculation for this bending force, although the one most commonly used is:

$$\text{Bending force} = \frac{EdA}{D}$$

where E = Elastic Modulas as given under 'Elongation of Wire Rope' – kgf/mm²
d = diameter of outer wire in rope – mm
A = Area in rope – mm²
D = Diameter of sheave or drum – mm

Size of Outer Wires in Rope

It is sometimes useful to know the size of the outer wires in ropes i.e. when estimating the amount of external wear or calculating bending stress. These can be calculated with reasonable accuracy for all constructions of 6 strand ropes using the following formula.

6 strand round strand

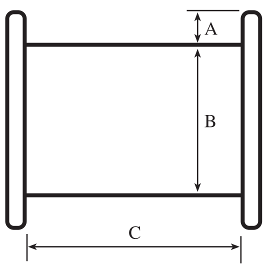
$$\text{Diameter of outer wires} = \frac{\text{Nominal diameter or rope}}{\text{No. of outer wires per strand} + 3}$$

Example:
26mm diameter 6 x 36 (14/7 and 7/7/1)
round strand
No. of outer wires per strand = 14

$$\text{Diameter of outer wire} = \frac{26}{14+3} = 1.5\text{mm}$$

Calculations of Drum Capacity

The following formula gives an approximate indication regarding length of rope of a given diameter (d) which can be installed onto a winch/drum.



Imperial

$$\text{Rope length (ft)} = \frac{(A + B) \times A \times C \times \pi}{12d^2}$$

where A, B, C and d are quoted in inches.

Metric

$$\text{Rope length (m)} = \frac{(A + B) \times A \times C \times \pi \times 10^6}{d^2}$$

where A, B and C are quoted in metres and d quoted in mm.

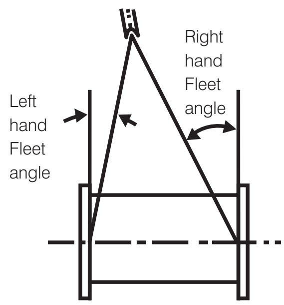
NOTE: Ropes are normally manufactured to a maximum oversize tolerance of 4%. Therefore the actual diameter 'd' could be nominal diameter + 4%.

⚠ WARNING

Wire rope will fail if worn-out, shock loaded,overloaded, misused, damaged, improperly maintained or abused.

- **Always inspect wire rope for wear, damage or abuse before use**
- **Never use wire rope which is worn-out, damaged or abused**
- **Never overload or shock load a wire rope**
- **Inform youself: Read and understand the guidance on product safety given in this catalogue; also read and understand the machinery manufacturer's handbook**
- **Refer to applicable directives, regulations, standards and codes concerning inspection, examination and rope removal criteria**

Protect yourself and others - failure of wire rope may cause serious injury or death!



Left hand Fleet Angle:	°
Right hand Fleet Angle:	°
Groove Pitch:	mm
Groove Radius:	mm
No. of Crossovers:	
Length of Crossovers:	mm

Rope Oscillation

Drum hoists operating with multiple layers of rope often experience severe oscillation of the rope between the headgear sheave and the hoist drum during some part of the hoisting cycle. Advice should be sought from BRIDON'S Mining Division.

How to order hoist ropes

Customer information					
I. Particulars of shaft:					
1. Suspended Hoist Rope (From Lowest level to Headgear pulley)					
2. Type of ventilation (upcast/downcast)					
3. Shaft water inflow					
4. PH value					
5. Availability of chloride content					
6. Range of temperature variation					
7. Other conditions affecting the rope					
II. Particulars of hoisting:					
1. Type of hoisting	One Rope		Multirope		
	Cage	Skip	Kibble	Counterweight	
2. Application	Mineral				
	Mineral & Manriding				
3. Speed of lifting, m/sec					
4. Acceleration of lifting, m/sec^2					
5. Preventative deceleration, m/sec^2					
6. Guides	If Available				
	Rope				
	Rigid:	Wood	Steel	Rollers	Shoe
III. Particulars of the winder:					
1. Type	Drum Winder	Friction Winder-tower or Ground Mounted Drum			
2. Drum diameter					
3. Drum width					
4. Diameter of Headgear pulley, (mm)					
5. Width of Headgear Pulley					
6. Diameter tolerance taking into account the bottom of the pulley					
7. Type of lining					
8. Diameter of deflector sheave (Tower mounted Friction winding only)					
9. Number of hoist ropes					
10. Number of balance ropes					
11. Type of balance ropes					
12. Weight of 1 m of balance ropes					
13. Loop radius of balance ropes					
IV. Particulars of the hoist conveyance:					
1. Mass of empty conveyance with suspension gear of hoist and balance ropes					
2. Mass of conveyance (2) or counterweight with suspension gear					
3 Mass of payload, t					
4 Number of cycles per day/month					
V. Particulars of the rope:					
1. Rope Specification					
2. Nominal diameter, mm					
3. Construction					
4. Lay Direction					
5. Type of core					
6. Weight of 1 m					
7. Length of the rope, m					
8. Number of individual lengths					
9. Preferred Lubrication					
10. Galvanised/Ungalvanised					
11. Rope Tensile					
12. Minimum Breaking Load, kgf					
13. Nominal Breaking Load, kgf					
14. Aggr. Breaking Load of all wires					
15. Lubrication	Core:	Strands	Rope:		
16. Safety factor: ratio of ABL of all wires to the end load	Without Mass of Ropes, min.				
	With Mass of Ropes, min.				
18. Causes of rope failure during operation					
19. Notes:					

Summary Technical Information (For guidance purposes only)

Bridon supply a range of 'Tiger' High Performance steel wire ropes specifically designed and manufactured to meet the needs of today's mine winder specifications and the demanding applications to which they are exposed. High performance ropes are normally selected by customers when they require the specific characteristics of improved performance, high strength, low extension or low rotation.

Rope Construction	Rope Modules at 20% of MBF kN/mm²	Torque Factor at 20% of MBF %	
		Ordinary	Langs
TIGER 6R F 6 x 7 Class	61.80	8.1	12.0
TIGER 6R F 6 x 19 Class	54.00	8.1	12.0
TIGER 6R F 6 x 36 Class	50.80	8.1	12.0
TIGER Dyform 6R F 6 x 7 Class	66.90	8.1	12.0
TIGER Dyform 6R F 6 x 19 Class	54.20	8.1	12.0
TIGER Dyform 6R F 6 x 36 Class	50.30	8.1	12.0
TIGER 6T F 6 x 8 Class Single layer	68.70	n/a	13.4
TIGER 6T F 6 x 25 Class Compound layer	61.80	n/a	13.4
TIGER 18M F 18 x 7 Class	42.30	n/a	6.6
TIGER 18M F 18 x 19 Class	41.80	n/a	5.6
TIGER Dyform 18 18 x 7 Class	65.70	n/a	4.5
TIGER Dyform 18 18 x 19 Class	65.70	n/a	3.8
TIGER 34M F 34 x 7 Class	41.20	n/a	4.1
TIGER 34M F 34 x 19 Class	40.70	n/a	5.1
TIGER 34LR 34 x 7 Class	72.60	n/a	0.8
TIGER 34LR 34 x 19 Class	72.60	n/a	1.8
TIGER Superflex 14 x 6	40.20	n/a	3.9
TIGER Superflex 17 x 6	38.30	n/a	2.6
TIGER Superflex 20 x 6	36.30	n/a	1.3
TIGER 6R CDR 6 x 19 Class	50.00	n/a	12.0
TIGER 6R CDR 6 x 25 Class	46.40	n/a	12.0
TIGER 6R CDR 6 x 31 Class	46.40	n/a	12.0
TIGER Dyform 6R CDR 6 x 19 Class	54.20	n/a	12.0
TIGER Dyform 6R CDR 6 x 26 Class	50.30	n/a	12.0
TIGER Dyform 6R CDR 6 x 31 Class	50.30	n/a	12.0
TIGER Zebra CDR 6 x 19	63.90	n/a	9.6
TIGER Zebra CDR 6 x 26	59.30	n/a	9.6
TIGER Zebra CDR 6 x 31	59.30	n/a	9.6
TIGER FL Hoist Class	98.10	Variable	
TIGER FL Aerial Track Class	110.00	Variable	
TIGER HL Guide Class	117.00	Variable	

Guide to Examination

The continued safe operation of lifting equipment, lifting accessories (e.g. slings) and other systems employing wire rope depends to a large extent on the operation of well programmed periodic rope examinations and the assessment by the competent person of the fitness of the rope for further service.

Examination and discard of ropes by the competent person should be in accordance with the instructions given in the original equipment manufacturer's handbook. In addition, account should be taken of any local or application specific Regulations.

The competent person should also be familiar, as appropriate, with the latest versions of related International, European or National standards such as ISO 4309 "Cranes - Wire ropes - code of practice for examination.

Particular attention must be paid to those sections of rope which experience has shown to be liable to deterioration. Excessive wear, broken wires, distortions and corrosion are the more common visible signs of deterioration.

Note: This publication has been prepared as an aid for rope examination and should not be regarded as a substitute for the competent person.

Wear is a normal feature of rope service and the use of the correct rope construction ensures that it remains a secondary aspect of deterioration. Lubrication may help to reduce wear.

Broken wires are a normal feature of rope service towards the end of the rope's life, resulting from bending fatigue and wear. The local break up of wires may indicate some mechanical fault in the equipment. Correct lubrication in service will increase fatigue performance.

Distortions are usually as a result of mechanical damage, and if severe, can considerably affect rope strength.

Visible rusting indicates a lack of suitable lubrication, resulting in **corrosion**. Pitting of external wire surfaces becomes evident in some circumstances. Broken wires ultimately result.

Internal corrosion occurs in some environments when lubrication is inadequate or of an unsuitable type. Reduction in rope diameter will frequently guide the observer to this condition. Confirmation can only be made by opening the rope with clamps or the correct use of spike and needle to facilitate internal inspection.

Note: Non-destructive testing (NDT) using electromagnetic means may also be used to detect broken wires and/or loss in metallic area. This method complements the visual examination but does not replace it.

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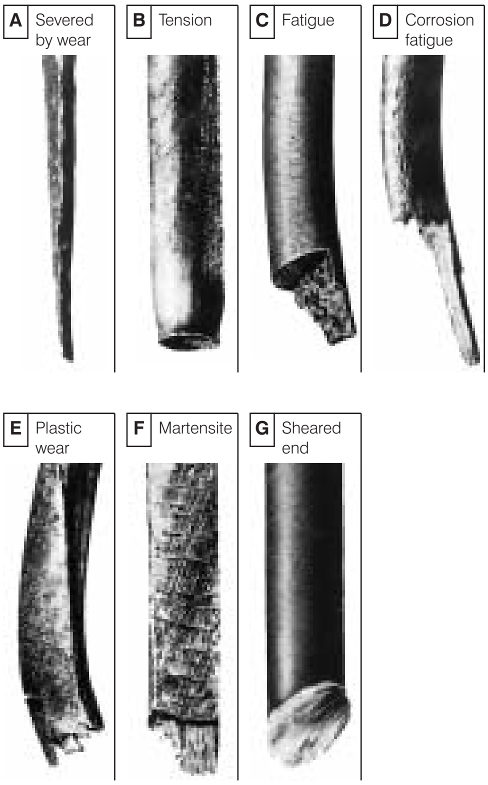
Some of the More Common Types of Wire Fractures Can Include:



Factors Affecting Rope Performance

Multi-coiling of the rope on the drum can result in severe distortion in the underlying layers.

Bad coiling (due to excessive fleet angles or slack winding) can result in mechanical damage, shown as severe crushing, and may cause shock loading during operation.

Small diameter sheaves can result in permanent set of the rope, and will certainly lead to early wire breaks due to fatigue.

Oversize grooves offer insufficient support to the rope leading to increased localised pressure, flattening of the rope and premature wire fractures. Grooves are deemed to be oversize when the groove diameter exceeds the nominal rope diameter by more than 15% steel, 20% polyurethane liners.

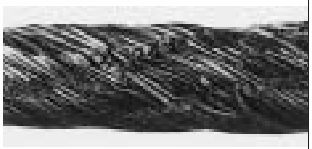
Undersize grooves in sheaves will crush and deform the rope, often leading to two clear patterns of wear and associated wire breaks.

Excessive angle of fleet can result in severe wear of the rope due to scrubbing against adjacent laps on the drum. Rope deterioration at the Termination may be exhibited in the form of broken wires. An excessive angle of fleet can also induce rotation causing torsional imbalance.

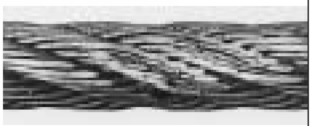
Troubleshooting Guide

Typical examples of Wire Rope deterioration

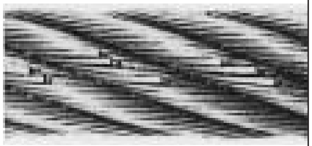
1 Mechanical damage due to rope movement over sharp edge projection whilst under load.



2 Localised wear due to abrasion on supporting structure.

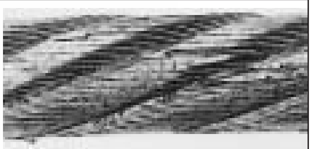


3 Narrow path of wear resulting in fatigue fractures, caused by working in a grossly oversize groove, or over small support rollers.



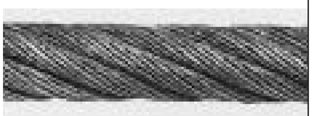
4 Two parallel paths of broken wires indicative of bending through an undersize groove in the sheave.

5 Severe wear, associated with high tread pressure.

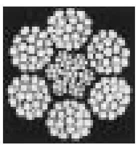


6 Severe wear in Langs Lay, caused by abrasion.

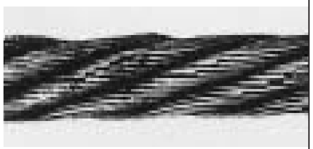
7 Severe corrosion.



8 Internal corrosion whilst external surface shows little evidence of deterioration.

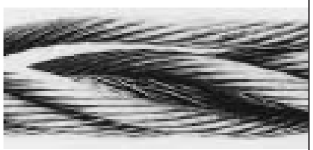


9 Typical wire fractures as a result of bend fatigue.



10 Wire fractures at the strand, or core interface, as distinct from 'crown' fractures.

11 Break up of IWRC resulting from high stress application.

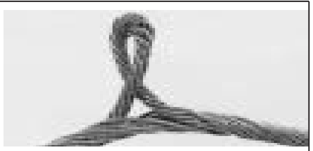


12 Looped wires as a result of torsional imbalance and/or shock loading.

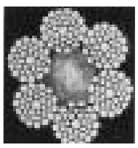
13 Typical example of localised wear and deformation.

14 Multi strand rope 'bird caged' due to torsional imbalance.

15 Protrusion of rope centre resulting from build up of turn.



16 Substantial wear and severe internal corrosion.



Troubleshooting Guide

The following is a simplified guide to common wire rope problems. More detailed advice can be obtained from any Bridon distributor. In the event of no other standard being applicable, Bridon recommends that ropes are inspected/examined in accordance with ISO 4309.

Problem	Cause/Action
Mechanical damage caused by the rope contacting the structure of the installation on which it is operating or an external structure - usually of a localised nature.	• Generally results from operational conditions. • Check sheave guards and support/guide sheaves to ensure that the rope has not "jumped out" of the intended reeving system. • Review operating conditions.
Opening of strands in rotation resistant, low rotation and parallel closed ropes - in extreme circumstances the rope may develop a "birdcage distortion" or protrusion of inner strands. ***Note - rotation resistant and low rotation ropes are designed with a specific strand gap which may be apparent on delivery in an off tension condition. These gaps will close under load and will have no effect on the operational performance of the rope.***	• Check sheave and drum groove radii using sheave gauge to ensure that they are no smaller than nominal rope radius +5% - Bridon recommends that the sheave and drum groove radii are checked prior to any rope installation. • Repair or replace drum/sheaves if necessary. • Check fleet angles in the reeving system - a fleet angle in excess of 1.5 degrees may cause distortion (see page 31). • Check installation method - turn induced during installation can cause excessive rope rotation resulting in distortion (See pages 42 - 54). • Check if the rope has been cut "on site " prior to installation or cut to remove a damaged portion from the end of the rope. If so, was the correct cutting procedure used? Incorrect cutting of rotation resistant, low rotation and parallel closed ropes can cause distortion in operation (See page 46). • Rope may have experienced a shock load.
Broken wires or crushed or flattened rope on lower layers at crossover points in multi - layer coiling situations. Wire breaks usually resulting from crushing or abrasion.	• Check tension on underlying layers. Bridon recommends an installation tension of between 2% and 10% of the minimum breaking force of the wire rope. Care should be taken to ensure that tension is retained in service. Insufficient tension will result in these lower layers being more prone to crushing damage. • Review wire rope construction. Dyform wire ropes are more resistant to crushing on underlying layers than conventional rope constructions. • Do not use more rope than necessary. • Check drum diameter. Insufficient bending ratio increases tread pressure.

Continued on next page

Troubleshooting Guide

Problem	Cause/Action
Wires looping from strands.	• Insufficient service dressing. • Consider alternative rope construction. • If wires are looping out of the rope underneath a crossover point, there may be insufficient tension on the lower wraps on the drum. • Check for areas of rope crushing or distortion.
"Pigtail" or severe spiralling in rope.	• Check that the sheave and drum diameter is large enough - Bridon recommends a minimum ratio of the drum/sheave to nominal rope diameter of 18:1. • Indicates that the rope has run over a small radius or sharp edge. • Check to see if the rope has "jumped off" a sheave and has run over a shaft.
Two single axial lines of broken wires running along the length of the rope approximately 120 degrees apart indicating that the rope is being "nipped" in a tight sheave.	• Check sheave and drum groove radii using sheave gauge to ensure that they are no smaller than nominal rope radius + 5% - Bridon would recommend that the sheave/drum groove radii are checked prior to any rope installation. • Repair or replace drum/sheaves if necessary.
One line of broken wires running along the length of the rope indicating insufficient support for the rope, generally caused by oversize sheave or drum grooving.	• Check to see if the groove diameter is no greater than 15% greater than the nominal rope diameter. • Repair or replace drum/sheaves if necessary. • Check for contact damage.
Short rope life resulting from evenly/randomly distributed bend fatigue wire breaks caused by bending through the reeving system. Fatique induced wire breaks are characterised by flat ends on the broken wires.	• Bending fatigue is accelerated as the load increases and as the bending radius decreases (see page 30). Consider whether either factor can be improved. • Check wire rope construction - Dyform ropes are capable of doubling the bending fatigue life of a conventional steel wire rope.

Troubleshooting Guide

Problem	Cause/Action
Short rope life resulting from localised bend fatigue wire breaks. Fatique induced wire breaks are characterised by flat ends on the broken wires.	• Bending fatigue is accelerated as the load increases and as the bending radius decreases (see page 30). Consider whether either factor can be improved. • Check wire rope construction - Dyform ropes are capable of doubling the bending fatigue life of a conventional steel wire rope. • Localised fatigue breaks indicate continuous repetitive bends over a short length. Consider whether it is economic to periodically shorten the rope in order to move the rope through the system and progressively expose fresh rope to the severe bending zone. In order to facilitate this procedure it may be necessary to begin operating with a slightly longer length of rope.
Broken rope - ropes are likely to break when subjected to substantial overload or misuse particularly when a rope has already been subjected to mechanical damage. Corrosion of the rope both internally and/or externally can also result in a significant loss in metallic area. The rope strength is reduced to a level where it is unable to sustain the normal working load.	• Review operating conditions.
Wave or corkscrew deformations normally associated with multistrand ropes.	• Check sheave and drum groove radii using sheave gauge to ensure that they are no smaller than nominal rope radius +5% - Bridon recommends that the sheave/drum groove radii are checked prior to any rope installation. • Repair or replace drum/sheaves if necessary. • Check fleet angles in the reeving system - a fleet angle in excess of 1.5 degrees may cause distortion (see page 31). • Check that rope end has been secured in accordance with manufacturers instructions (see page 46). • Check operating conditions for induced turn.
Rotation of the load in a single fall system.	• Review rope selection. • Consider use of rotation resistant or low rotation rope.
Rotation of the load in a multi - fall system resulting in "cabling" of the rope falls. Possibly due to induced turn during installation or operation.	• Review rope selection. • Consider use of rotation resistant or low rotation rope. • Review installation procedure (See pages 42 - 54) or operating procedures.
Core protrusion or broken core in single layer six or eight strand rope.	• Caused by repetitive shock loading - review operating conditions.

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Troubleshooting Guide

Problem	Cause/Action
Rope accumulating or "stacking" at drum flange - due to insufficient fleet angle.	• Review drum design with original equipment manufacturer - consider adding rope kicker, fleeting sheave etc.
Sunken wraps of rope on the drum normally associated with insufficient support from lower layers of rope or grooving.	• Check correct rope diameter. • If grooved drum check groove pitch. • Check tension on underlying layers - Bridon recommend an installation tension of between 2% and 10% of the minimum breaking force of the wire rope - Care should be taken to ensure that tension is retained in service. Insufficient tension will result in these lower layers being more prone to crushing damage. • Make sure that the correct rope length is being used. Too much rope (which may not be necessary) may aggravate the problem.
Short rope life induced by excessive wear and abrasion.	• Check fleet angle to drum. • Check general alignment of sheaves in the reeving system. • Check that all sheaves are free to rotate. • Review rope selection. The smooth surface of Dyform wire ropes gives better contact with drum and sheaves and offers improved resistance to "interference" betweeen adjacent laps of rope.
External corrosion.	• Consider selection of galvanised rope. • Review level and type of service dressing.
Internal corrosion.	• Consider selection of galvanised rope. • Review frequency amount and type of service dressing. • Consider selection of plastic impregnated (PI) wire rope.