

Care of wires and ropes on board ships

Causes of damage to wires and ropes on board can be categorised into five types: abrasion, corrosion, crushing, cutting-in and stretch. The general condition of a wire should be monitored whenever it is in use and specific inspections should concentrate on signs of deterioration and damage

Uses on board

The most common uses of wires and ropes on board modern vessels include:

- Accommodation ladders and gangways
- Cranes and hoists
- Elevators
- Lifeboat / rescue boat / life raft davits
- Moorings
- Lifting strops and slings.

Causes of damage to wire ropes

There are many causes of damage to wires and ropes on board, these can be categorized into 5 types:

Abrasion

Generally due to pulleys, sheaves, rollers and/or fairleads being seized or otherwise damaged. This is a common form of damage to mooring wires – repeated dragging by the stevedores over concrete knuckles and along the quay is probably the most common cause. Insufficient internal lubrication results in internal wear, otherwise known as *fretting corrosion*. Individual wires and strands rub together resulting in rust-like damage showing between the exterior strands. Crane wires are

frequently found to have the individual outer strands *flattened* due to non-rotating or under-sized sheaves, or contact with other strands on the drum itself.



Abraded wire rope, showing localised damage to individual wires

Corrosion

Caused by unprotected wires being exposed to salt water and the elements. The smaller the diameter of the wire, the less effective the internal lubrication.

Crushing

Uneven spooling on a drum can result in wires crossing. With load on the wire, this can lead to the lower layers of wire becoming crushed, reducing the effecting breaking strain of the wire.

Cutting-in

Occurs when a rope buries itself when under tension beneath poorly spooled lower layers, potentially leading to jamming which could result in the wire kinking, being crushed or even counter-rotation.



Rope buried in amongst lower layers

Fatigue

Fatigue is the result of frequent bending of the wire under load, particularly round under-sized sheaves, rollers, etc. and due to kinking. Fatigue is exacerbated by poor lubrication and corrosion. Fatigue results in the individual strands cracking and eventually failing.



Fatigue-induced wire breaks are characterised by flat ends on the broken wires

Stretch

More common in elevator wires, this is the result slight differences in diameter and/or elastic properties. Compensation mechanisms are usually fitted, but it can lead to wire slippage on the sheaves.

Routine inspection of wire ropes

The required intervals between on board inspections should be documented by the manufacturer and is dependent upon the use, size and construction of the wire. These intervals should be transferred to the vessel's planned maintenance system.

The general condition of a wire should be monitored whenever it is in use. Specific inspections should however concentrate on signs of deterioration and damage. A formal inspection should be undertaken by a responsible person before work commences and if shock-loading is suspected. The time interval between subsequent inspections can be reduced by the competent person due to the condition of the wire. ISO 4309:2004 states that for crane wire, the following points should be covered by examination:¹

Although the wire rope shall be examined throughout its length, particular care shall be taken at the following locations:

- a) The termination points of both moving and stationary ropes;
- b) The part of the rope which passes over the block or over sheaves;
- c) In the case of cranes performing a repetitive operation, any part of the rope which lies over sheave(s) while the crane is in a loaded condition;
- d) That part of the rope which lies over a compensating sheave;
- e) Any part of the rope which may be subject to abrasion by external features (e.g. hatch coamings);
- f) Internals of the rope, for corrosion and fatigue;
- g) Any part of the rope exposed to heat.

These should stand as guidelines for inspecting wires associated with lifeboat / life raft / rescue boat davits, accommodation ladders and gangways etc.

Records should be maintained detailing the changing condition of a wire throughout its life-cycle. Details that should be recorded include the number and location of individual broken wires², any flattening of the surface of the wire, any signs of abrasion, kinking, etc. This would allow for progressive monitoring of the wire, and allow for programming additional maintenance and for replacement wires to be purchased in good time.

Discard criteria

Deterioration frequently is the result of a combination of factors, including:

- The nature and number of broken wires
 - Broken wires at the terminations
 - Localised grouping of wire breaks
 - The rate of increase of wire breaks
 - The fracture of strands
- Reduction of rope diameter
- Decreased elasticity
- Wear
- Corrosion – internal and external
- Deformation, including 'bird cages', kinks, etc
- Damage due to heat or electric arcing
- Rate of increase of permanent elongation.

¹ Section 3.4.2.1

² See section on Discard criteria

The competent person conducting the inspection should determine whether the deterioration has been caused by a deficiency in the crane, davit, winch or associated equipment including rollers and fairleads, and take appropriate measures to ensure these deficiencies are rectified.

The individual extent of deterioration should be assessed and expressed as a percentage of the particular wire's discard criteria. When the cumulative value at any position reaches 100%, the rope should be discarded. An individual wire rope's discard criteria will be established by the manufacturer.

Nature and number of broken wires

The number of broken wires allowed for any given wire rope would depend on designed use / function of the wire. For example, a single layer 6x19 wire core rope should be discarded if 3 or more wires are seen to be broken over a length equivalent to 6 diameters, and a single layer 6x36 wire core rope should be discarded if 9 or more wires are seen to be broken.

6x19 wires are general purpose wires, used on sheaves, reels, hoists, etc. and 6x36 wires are commonly used as lifeboat falls, on davits and cranes. Broken wires at terminations are indicative of high stress loadings at the termination, sometimes associated with incorrect fitting of the termination.

Where broken wires are grouped very close together, the wire should be discarded. If this grouping occurs in a length less than 6 x diameter or is concentrated in any one strand, it may be necessary to discard the rope even if the number of breaks is less than the maximum number allowed for that size / type of rope.

The rate of increase in the number of broken wires may be used to pre-plan the replacement of that wire. Fatigue is the predominant cause of broken wires, this number will progressively increase over time. Any fractured strands should immediately warrant the wire unusable and as such should be discarded.

Reduction of rope diameter

Deterioration of the core is a common cause of reduction of a rope's diameter, and can be caused by:

- Internal wear and wire indentation
- Internal wear due to wire bending
- Deterioration of a fibre core
- Fractured internal layers in a rotation-resistant rope

If these factors cause the rope's diameter to decrease by more than 3% of the rope's nominal diameter³

(rotation-resistant ropes) or 10% (other ropes), the rope should be discarded even if no broken wires are sighted.

Decreased elasticity

Under certain circumstances usually associated with a rope's working environment, it can sustain a substantial decrease in elasticity and would therefore be unsafe.

Decreased elasticity is difficult to detect, but is usually associated with the following:

- Reduction in rope diameter
- Elongation of the rope lay length⁴
- Lack of clearance between individual wires and strands due to compression
- Appearance of fine brown powdery residue between the strands
- Increased stiffness

External wear

Is shown by abrasion of the crown, or outer wires and is the result of rubbing under load. This is particularly evident on moving ropes and appears as flattened surfaces on the outer wires.

Wear is promoted by a lack of or incorrect lubrication, and by the presence of dust or grit. Wear reduces the actual rope diameter.

External and internal corrosion

Corrosion is prolific in the marine environment, and diminishes the breaking strength of the rope by reducing the cross-sectional area of the individual wires, which increases the likelihood of fatigue, cracking and reduces the elasticity of the rope.

External wire corrosion is easily detected.

Internal corrosion is invariably the result of insufficient internal lubrication. General indications of internal corrosion include the appearance of fine brown powdery residue between the strands, where the rope bends around sheaves there is usually a reduction in diameter. In stationary wires there is sometimes an increase in wire diameter due to the build-up of rust, and wire breaks between or within the strands. Severe internal corrosion renders the rope unusable.

³ Designated diameter of the rope, can be found on the certificate

⁴ The distance, measured along the rope, required for the outer wire of a spiral-laid rope and the strands of a stranded rope to make one complete turn (or helix) about the axis of the rope

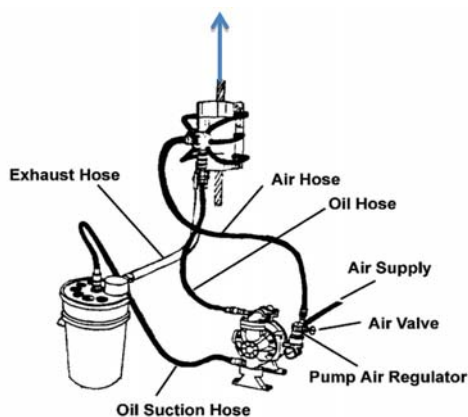
Inspection and maintenance

Mooring wires are frequently left exposed to the elements, which on the forward mooring deck is generally wind and salt water, whereas down aft the wires may be exposed to sea spray and funnel emissions. These are corrosive environments where poorly protected or lubricated wires will deteriorate. Crane wires, lifeboat falls etc. are also left exposed to the elements and suffer accordingly.

Ideally, wires should be removed from their drums for a thorough inspection, care being taken that broken wires don't snag and cause injury to those personnel handling the wires.

Once the inspection is complete, wires should be cleaned and lubricated. One of the most common methods we have seen of greasing wires is either by the use of a rag covered in grease or with brushes dipped in grease and smeared over the wire. This is an ineffective method, as the wire isn't cleaned of the old grease, there is no grease penetrating to the core of the wire etc., new grease is merely spread over the surface of the old grease, salt, soot and other contaminants. This layer of grease only serves to make a mess of anything that comes into contact with the wire.

There are proprietary wire rope cleaners/lubricators available, many of which consist of a sleeve clamped around the wire, into which compressed air forces grease or a specialised oil. Some of these cleaners have rotary collar brushes that follow the grooves of the wire, others have rubber collars; all scrape off the old grease before injecting fresh lubricant into the wire as the wire is slowly pulled through the sleeve. The collars are interchangeable, so different sizes can be used for different size wires. These can generally be used in situ, with adaptable flexible mountings, so can be used on cranes, davits, winches, etc. There are also a number of fixed systems available whereby the lubricating unit is permanently rigged on the crane or other appliance.



Example of a portable wire cleaning/lubrication system found on many vessels

Another method we have seen for cleaning wires (except mooring wires as they tend to be too big) is for the wire to be removed completely from its spool and placed in a container of kerosene or similar. This dissolves the old grease, right into the core of the wire. When new grease is applied to the outside of the wire, the remaining kerosene draws fresh lubricant into the wire.

Lubricants applied to wire ropes provide a dual form of protection such that individual wires are protected from each other and the whole wire is protected from the corrosive action of sea water. In order to understand the importance of lubrication, it is necessary to understand that a wire, when in use, is a dynamically complex mechanical unit comprising of a number of moving parts. As a wire passes over a sheave or round a roller it is subjected to corrosion, bending, tension and compressive stresses as it equalises the effects of the load imparted upon it. The lubricant added to the wire during the manufacturing process allows this equalisation process to occur with the minimum of abrasion / deterioration to the individual wires in a strand. It should therefore be apparent that applying a coating of grease to an old contaminated layer of grease serves little purpose as it cannot penetrate the wire.

When inspecting wires, thought should also be given to all sheaves, rollers, fairleads etc. that the wire utilises. All should be inspected and their efficient operation confirmed. Rough surfaces on rollers and fairleads should be ground smooth, rollers should all rotate freely.

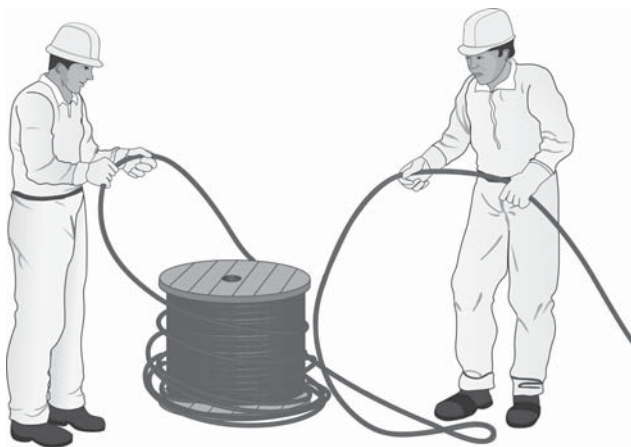
When the inspection is complete and the wire has been properly greased, care should be taken to ensure that the wire is re-spoiled correctly, with suitable tension to ensure that there are no loose or riding turns, and that when next used under load, the wire cannot bury itself on the spool.

Should a wire be found to require replacing, it is essential that the specifications of the new wire are at least equal to those of the wire being replaced. The certificate for the new wire should replace that of the wire being discarded in the Cargo Gear Register or similar, depending on the wires intended use, and all the vessel's PMS updated accordingly.

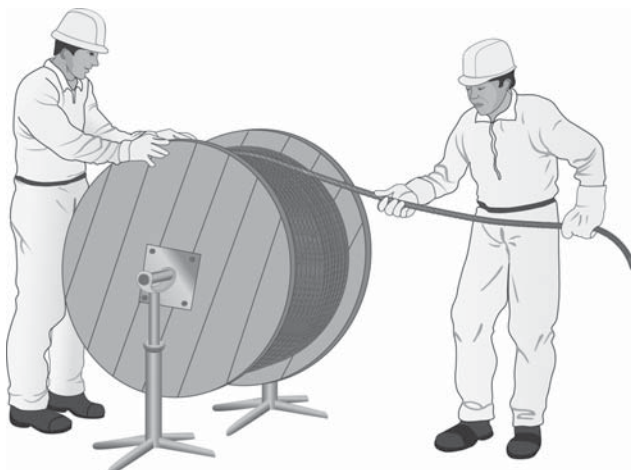
Spare wires should be stowed under cover, away from the elements and chemicals. Wires should be removed from a coil by rolling the coil, not laying the coil flat and pulling the end – this introduces twists into the wire. When stored on a reel, the reel should either be placed on a turntable, or a shaft placed through the centre of the reel and the wire pulled as the reel rotates. Reels

should not be rolled, nor should the reel be placed on the deck and the wire just pulled off the static reel.

Records should be maintained of all inspections, maintenance and renewals.



Incorrect method of unreeing a wire, this method induces twists, which could lead to kinks in the wire



Correct method for unreeing a wire rope, either using a turntable (vertical) or centre spindle (horizontal)

Causes of damage to man-made or natural fibre ropes

Any form of rope is liable to wear and mechanical damage and can be weakened by various means, including chemical, heat and light. Regular inspection is essential to ensure that ropes are serviceable before use.

Chemicals and solvents

There are a wide variety of potential chemical contaminants to be found on board modern ships.

Nylon ropes show signs of chemical attack by local weakening or softening of the rope, such that surface fibres can be plucked or rubbed off in a powdery form in more extreme cases. Solutions of mineral acids cause rapid weakening. Nylon is unaffected by alkalis and

many oils at normal temperatures, although it swells when in contact with certain organic solvents.

Exposure, including airborne sprays, should be avoided wherever possible. If contamination is suspected, the rope should be washed out in cold water. If there is any doubt, the rope should be discarded.

Polyester ropes show signs of chemical attack by local weakening or softening of the rope such that surface fibres can be plucked or rubbed off in a powdery form in more extreme cases. Hot solutions of strong alkalis progressively dissolve the fibres causing gradual loss in mass and a corresponding loss in strength. Resistance to acids is generally good. No acidic solutions should be allowed to dry on a rope. If any such contamination is suspected, the rope should be washed out in cold water. If there is any doubt, the rope should be discarded. Resistance to hydrocarbon oils and common organic solvents is good although it may swell in contact with certain chlorinated solvents. Attack by concentrated phenols is severe and should be avoided.

Polypropylene ropes are unaffected at normal temperatures by alkalis and acids, but are attacked by some organic solvents such as white spirit, xylene and meta-cresol. Rope contact with wet paint, coal tar or paint-stripping preparations should be avoided.

Cuts

Cuts, contusions or careless use may cause internal as well as external damage. Indications include local loosening or rupturing of yarns and/or strands.

External wear

External wear due to dragging over rough surfaces is very common, resulting in surface chafing or *filamentation*. In severe cases, the outer strands become so worn that they become flattened and the outer yarns are severed. Generally speaking, some degree of external wear is inevitable and can be harmless depending on the severity. Many man-made ropes have high abrasion-resistance levels.

Heat

Heat may in certain cases cause fusing of the yarns and strands. Rope should never be dried adjacent to a heat source as some man-made fibres may be damaged with no obvious warning. Surging of polypropylene ropes when under tension during mooring operations for example can cause sufficient frictional heat at the points of contact resulting in the fusing of the surface yarns. This effect can be reduced by using more turns around the drum end or capstan.

Internal wear

Internal wear is caused by repeated flexing of the rope, particularly when wet, and by particles of grit etc. that may have been picked up and worked their way into the rope. This may be indicated by excessive looseness of the strands and yarns, or the presence of powdered fibres.

Local abrasion

Local abrasion as opposed to general external wear may be caused by the passage of the rope over /round sharp edges when under tension and may result in serious loss of strength. While slight localised damage may be considered harmless, serious reduction in the cross-sectional area of a strand, or a lesser degree of abrasion to a number of strands in the same area warrant consideration for rejection of the rope. Protection in way of areas prone to abrasion should be considered.

Mildew

Mildew does not attack nylon, polyester or polypropylene ropes. However, it is recommended that no ropes are left flaked or coiled on deck longer than is necessary. Ropes facing prolonged storage on deck should be stowed on gratings, pallets etc, to allow for drainage and ventilation and covered to protect them from the elements.

Repeated loading

Nylon and polypropylene ropes have good resistance to damage caused by repeated loading, but permanent elongation may occur as these ropes have poor elastic memory, particularly polypropylene. As a consequence, once they have been over-stretched, the available remaining 'spring' is reduced.

Ultra violet degradation

Man-made fibre ropes, in particular polypropylene, suffer from UV degradation, where the outer, exposed strands lose any colour, go brittle and powdery.

Routine inspection of ropes

The smaller the diameter of the rope, the more serious the effect of the weakness; consideration should therefore be given to the relationship between surface and cross-sectional areas when examining ropes. The rope should be examined on all sides, and the lay opened / strands untwisted to inspect the condition of the inner strands and yarns.

Apart from a visual inspection by the crew prior to berthing and when alongside, mooring ropes should be periodically inspected as part of the vessel's planned maintenance system. These inspections should include general and localised wear, and splices.

We would not recommend the use of short splices to re-join a mooring rope that has had a damaged length removed, as these are of a lesser strength than the rope itself.

When inspecting ropes, the entire mooring system should be considered, including rollers, fairleads, bitts, drum ends, etc. Any rough or rusted surfaces should be ground smooth, rollers should freely rotate and there shouldn't be too much paint on drum ends and bitts as this detaches and gets embedded into the rope increasing the likelihood of internal wear and the subsequent loss in strength of the rope.

Consideration should be given to areas of frequent abrasion i.e. the eye on a mooring rope, lengths of lifeboat painter that rub against railings, etc.

Discard criteria

It is difficult to define a standard for acceptance and rejection, as a lot depends on the intended use of the rope and its likely loadings. In practice, the assessment should be based on the general condition of the rope. If there is any doubt as to the serviceability or safety of a rope, it should be withdrawn from service.

Acknowledgements: Unreeling drawings and rope damage photos courtesy of Witherby's and Bridon International