ESTA GUIDELINE GD24001-EN

Inspection of Winch Gearboxes used on Mobile Cranes

May 2024

CONTENT

SUPPORTING THE BEST PRACTICE GUIDE

This Best Practice Guide for the inspection of winch gearboxes on mobile cranes is the result of the joined effort of different international stakeholders in the world of mobile cranes. The document has been composed under the guidance of the European association of abnormal road transport and mobile cranes (ESTA)[1].

The following stakeholders have supported the development of this Best Practice Guide:

Stakeholder	Country	Type of player
Bosch Rexroth AG	Germany	Gearbox manufacturer
ESTA	The Netherlands	Association
Liebherr-Components Biberach GmbH	Germany	Gearbox manufacturer
Liebherr-Werk Ehingen GmbH	Germany	Crane manufacturer
Mammoet B.V.	The Netherlands	Operating company
Manitowoc Crane Group Germany GmbH	Germany	Crane manufacturer
OELCHECK GmbH	Germany	Laboratory
Polaris Laboratories	Poland	Laboratory
Sarens N.V.	Belgium	Operating company
Siebenhaar Antriebstechnik GmbH	Germany	Gearbox manufacturer
Tadano Europe GmbH	Germany	Crane manufacturer
TotalEnergies LubAnac	Belgium	Laboratory
ZOLLERN GmbH & Co KG	Germany	Gearbox manufacturer

LEGAL NOTE

This Best Practice Guide neither addresses each and every imaginable scenario, nor is it a binding interpretation of the existing legal framework. It does not and cannot replace the study of the relevant directives, laws and regulations. In addition, the specific features of different products and their various applications have to be taken into account (see related operating instructions of the equipment used). This is why the assessments and procedures referred to in this paper may be impacted by a large variety of circumstances.

The information in this document is for guidance only. The authors accept no liability for any actions taken as a result.

FOREWORD

This guidance was developed by ESTA to provide information on the necessity and content of inspections of winches/gearboxes on mobile cranes. Currently some confusion can be seen with regard to the so called 10-year general overhaul of winches aka major inspection, in particular when there is still a significant amount of theoretical lifetime of the gearbox remaining.

[1] Further information about ESTA can be found under https://estaeurope.eu/

1. SUMMARY

This guidance applies for mobile cranes as defined in EN13000 irrespective of their make and age. With technology developing in several fields, amongst them e.g., lubrication technology, material, recommendations given can be generic only. They are to be used if no specific instructions are given in the crane's documentation.

Mobile cranes and their components are designed for a limited lifetime under an assumed load spectrum, the so-called **design life**. The variations in use of a crane will lead to differing **service life** of cranes. The service life of structure and components may differ significantly as the structure is loaded only with one load cycle per lift, but components, e.g., winch gearboxes are subjected to many loading cycles during the same lift.

To prevent accidents from failing gearboxes when reaching their design life, many countries have introduced legally required periodic assessments of winches/gearboxes to stop their use beyond design life. The usage of the winch over a period (typically 1 year) is recorded and added to previous usage calculating the total usage (service life), which is compared with the design life of the gearbox. Provided that the resulting **remaining lifetime** is still exceeding the expected service time in the next period, the winch may be used for the following period.

This method is used since many years and is mandatory by law in a number of countries[2]. Information about the design life of the crane and its winches, and the method to calculate and record remaining lifetime is included in the crane documentation (see Annex A – Calculating the remaining Lifetime) together with information for periodic inspection of winches.

When introducing the assessment of the remaining life, a so-called general overhaul after 10 years aka major inspection was added as precautionary measure. Meanwhile users of mobile cranes have access to more advanced monitoring of the winches/gearboxes with results which give reason to question the requirement of a 10-year general overhaul.

Whereas the calculation of remaining life is based upon usage, the fixed 10-year general overhaul for the winches/gearboxes found in many documentations is an arbitrary point in time. With the industry experience available as of today, there is a better way than requiring a general overhaul at a fixed point in time, provided, that conditions of winches/gearboxes are monitored regularly.

Following the guidance for inspections given in this Best Practice Guide will enhance safety and likely reduce costs by:

- avoiding accidents or unintended downtime,
- avoiding general overhaul at the end of the 10-year period,
- supporting care of the gear oil, reducing oil changes and reducing waste oil.

The purpose of this Best Practice Guide is to provide information about the amount and technical content for such inspections and to clarify when a general overhaul of the winches may be required.

2. SCOPE

The scope of this Best Practice Guide is to provide all stakeholders in the European mobile crane industry with information and guidance for inspections of winches/gearboxes on mobile cranes[3] to ensure their safe use and to align the methods for assessment of winches/gearboxes.

This document does cover hydraulic drives for winch applications, but does not deal with specific issues of electric drives (e.g. inertia of electric motor increasing the braking energy).

Note: Some provisions of this guidance nevertheless apply for electrical drives as well.

The theoretical design life as determined by the gearbox manufacturer is the decisive limit found in the crane's documentation. Reaching this limit requires the gearbox taken out of service.
Regular thorough assessments of the winches/gearboxes including the calculation of the consumption of theoretical lifetime supersede the need for a general overhaul at a fixed time limit of 10 years[4].

This document includes information about the technical background and provides guidance on inspections and acceptance criteria when assessing the results of inspections. This Guide specifies minimum requirements for inspections of winches/gearboxes and the evaluation of their results by collecting existing and relevant industry guidance including the state-of-the-art in relation to the interpretation of oil samples.

Local legal requirements must always be considered and should any contradictions occur between this Best Practice Guide and applicable local regulations, then local legislation shall take precedence. If, however, this guideline requires a higher standard than local legal requirements, then the guideline should be applied, thereby positively contributing to the local requirements. Instructions provided by the original equipment manufacturer (OEM) stipulated in the cranes' manual must be adhered to. If, however, this guideline gives guidance to topics in addition of those specified in the manual, then the guideline should be applied thereby positively contributing to the manual.

[2] This Guide does not deal with the details of legal requirements for need and frequency of inspections and formal qualification of competent persons per country, such details need to be looked up in national legislation.
[3] The procedures for inspection can be applied in a similar way to e.g., mobile self-erecting tower cranes
[4] A fixed threshold at 10 years of winch service life as period followed by a general overhaul is too rigid in comparison to the varying usages.

3. DEFINITIONS

3.1 Check

A check refers to a more cursory examination, with the intention of verifying that everything is in order, often carried out prior commencing daily work. It involves a quick and simple analysis of the subject, often requiring little specialized knowledge or equipment.

3.2 Competent Person

Person who has the necessary practical and theoretical knowledge and the necessary experience of the crane and equipment used in the lifting operation /ISO 4306–1/.

Note: There may be legal requirements regarding the qualification and potential appointment of such persons stipulated in national law.

3.3 Design Life

Estimation of the allowable service life of a crane based on its original design specifications and taking into consideration the stress cycles and stress collectives (design constraints) before a special assessment and general overhaul are required

Note 1: The design life of a crane as a whole is usually governed by the life of a limited number of critical components (see ISO 12482-1). [...] /ISO 4306–1/

Note 2: In this Guidance the design life is related to winches in particular gearboxes, at the end of the design life of a winch a general overhaul is required.

3.4 General Overhaul

All refurbishment and maintenance actions based upon a special assessment (SA), required to extend the safe operation life of crane /ISO 4306–1/.

Note 1: In the context of this Guidance a special assessment, aka major inspection, is a thorough examination and evaluation of a winch.

Note 2: In the context of this Guidance a general overhaul of a gearbox is required at the end of the service life of this component or after the occurrence of an extraordinary event creating unusual conditions which may have impacted the performance; examples for winches/gearboxes are: shock load from external overloading.

Note 3: In the context of this Guidance a general overhaul of a gearbox may create an additional design life depending on a commercial agreement between customer and gearbox manufacturer / OEM.

3.5 Inspection

All relevant activities for the inspection of a crane including testing, as applicable /ISO 4306–1/.

Note: In the context of this Guidance inspection refers to a more thorough examination of winches, with the intention of identifying issues or defects. It involves a careful and detailed analysis of the subject, requires specialized knowledge or equipment.

3.6 Maintenance

Set of activities intended to keep a crane in, or to restore it to, a state in which it can perform its required function.

Example: Monitoring, test and measurement, replacement, adjustment, repair, administrative action (in some cases). /ISO 4306-1/

3.7 Oil Analysis

Oil Analysis is a laboratory analysis of a lubricant's properties, suspended contaminants and wear debris. It is performed during routine maintenance to provide meaningful and accurate information on lubricant and component condition.

3.8 Remaining Lifetime

Estimation of the (theoretically) remaining amount of design life of the crane and/or its components based on the original design specifications and actual usage.

3.9 Service Life of Winches/Gearboxes

Duration of time when the winch/gearbox is in use, beginning when the original owner starts using the winch/gearbox (puts the component in service) and ending when use ceases. Service life does not begin at the time of manufacturing and does not restart when the component changes ownership.

3.10 Winch

Mechanism which transmits pull by means of a flexible element (rope, chain) from a powerdriven drum, for example a drum hoist, friction hoist or capstan /ISO 4306–1/.

Note 1: For the purposes of this Guidance a winch is understood as an assembly of drum, gearbox, holding brake (may be included in the gearbox), hydraulic motor and hydraulic valves to control the drive and serve as dynamic brake. The gearbox may be placed inside of the drum or besides the drum.

Note 2: On mobile cranes winches are used to wind and unwind ropes loaded and unloaded, used for lifting (hoisting) loads and adjusting booms.

4. TECHNICAL BACKGROUND

4.1 Need for Inspecting and Checking Winches

Winches and their gearboxes on mobile cranes are suspending the load and/or the boom system, will wear under load and may suffer from fatigue. To prevent failure of winches due to wear and/or fatigue (see below) with potentially catastrophic consequences, their usage needs to be monitored and regular inspections are required.

Inspections are carried out visual, functional and audible, include oil analysis and the determination of the remaining lifetime of the gearbox.

Oil analysis will indicate wear and at the same time ensure the quality of the oil preventing excessive wear. Regular oil sampling and oil care may avoid unnecessary oil exchanges, thus extending the lifetime of the oil, likely reducing costs, and can have a positive environmental effect by avoiding waste oil.

Gearbox fatigue is not visible and can often, even after disassembly for inspection with special test methods, not be detected reliably.
Thus, a comparison of accumulated usage with the calculated design life to determine the remaining lifetime is needed to avoid failing caused by fatigue.

Note: More detailed explanations on wear and fatigue mechanisms related to gearboxes are given in clauses 4.2 and 4.3 as well as in Annexes F.2 - Wear and F.3 - Fatigue.

Inspection and maintenance intervals shall be taken from the instructions of the manufacturer, but should at least be performed once per year (annual inspection).]

The general overhaul after 10 years, if stipulated in the instructions, may be skipped if the provisions of this Guidance are followed.

Extraordinary loadings during use, e.g., unintended dynamics from a load "falling into the hook" require extra inspections by a competent person or the equipment manufacturer.

4.2 Wear

Wear of technical structures and mechanisms occurs at or just below the surface of parts in contact under pressure which move in relation to each other. Wear damages, gradually removes or deforms solid surfaces. The wear rate over time usually has a progressive characteristic. Worn out parts will not be able to execute their function as intended; a worn-out gear will not be able to take the intended load momentum and may fail suddenly.

Wear mechanisms which may occur at gearboxes are described in Annex F.2 - Wear.

4.3 Fatigue

Fatigue occurs in machinery, where elements on which stresses are acting may start accumulation of damage until a failure occurs. Often fatigue on technical structures is difficult to detect or becomes visible only when it is too late. Winches/gearboxes (e.g., teeth in a gearbox under bending stress) may suffer from fatigue. The stage of fatigue cannot be determined as it happens inside the material. Observing the accumulated load cycles (service life) in comparison to the design life is important.

More information on fatigue is given in Annex F.3 - Fatigue.

4.4 Extraordinary Wear and Fatigue, potential Issues

Wear and fatigue as describe in clauses 4.2 and 4.3 will occur during the operation of a winch, but will not lead to failure during the foreseen design life, if the component is operated as intended.

The service life of a winch may additionally be affected by a number of external influences causing extraordinary wear and fatigue, reducing the lifetime, for example:

- Overloading due to use of the crane not in accordance with intended use and regulations,
- Insufficient maintenance, e.g., oil change intervals/monitoring not followed,
- Extreme acceleration or deceleration of the load or the load falling into the ropes,
- Maintenance errors, e.g., wrong oil, mixture of oils, in-correct oil level (too low or too high) or contamination when changing the oil (see clause 4.5.6),
- Assembly errors during repair and maintenance,
- Leaks that have been neglected,
- Incorrectly set safety equipment, which may not limit loads or movements as intended by design,
- Concealed damage caused by previous accidents,
- Extreme ambient conditions such as low or high temperatures, aggressive atmosphere or dust and dirt.

Note: This behaviour can be compared with a tire which has, due to wear and environmental influences, a limited lifetime. The user of the vehicles has a big influence on the lifetime of the tires, which may be reduced significantly by wrong tire pressure (too high, too low), harsh cornering, excessive acceleration and braking, etc.

4.5 Design of Winches

4.5.1 General

Mobile cranes and their components including gearboxes are designed for a limited lifetime assuming a “standard use” in terms of loads and load cycles. Information about the assumed “standard use” are documented as classification of the crane and its components in the instruction manual. To ensure safe operation, the crane and its components need to be inspected regularly, in particular if the individual use differs from the assumed “standard use”.

The picture below shows the cross section of a typical planetary gear used in mobile crane applications. The areas for inspection are described in the following clauses.

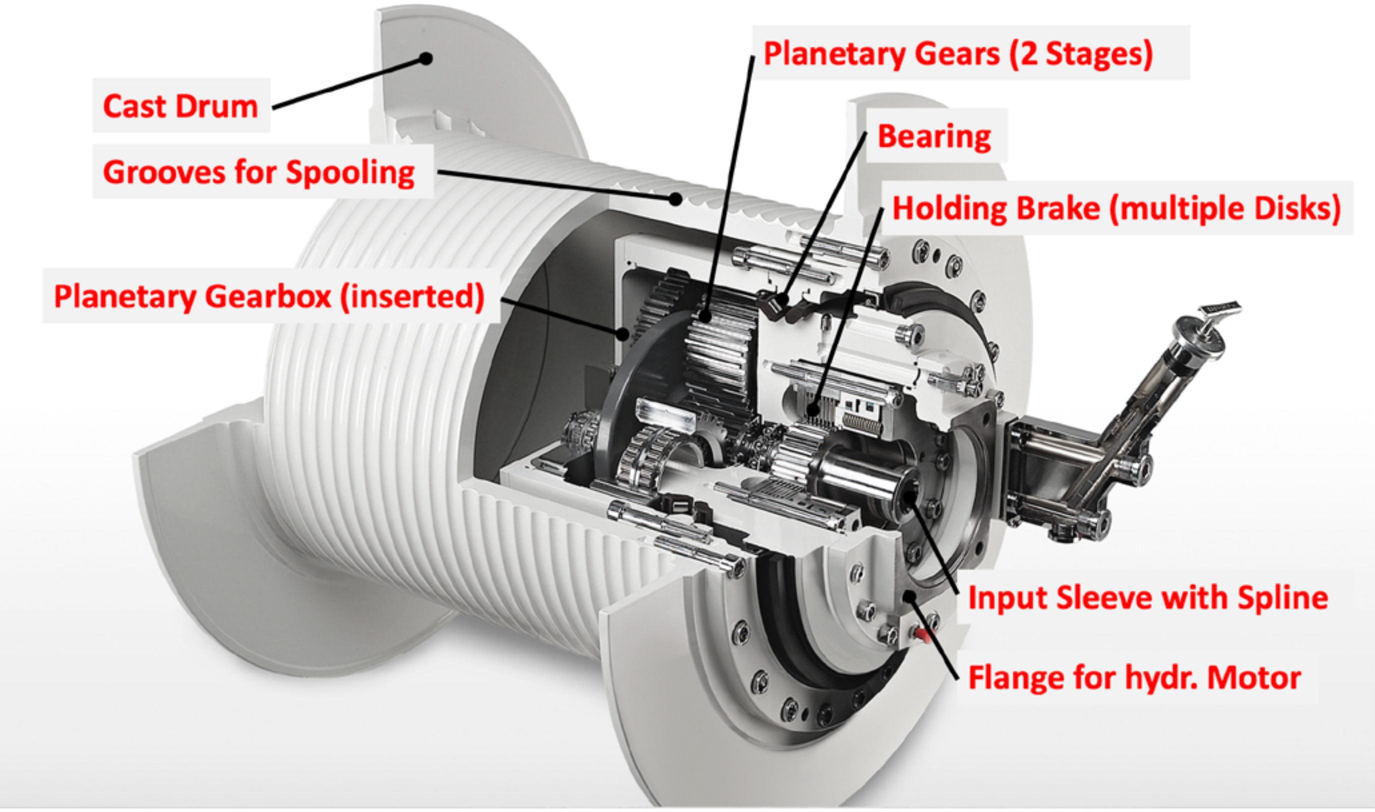


Figure 2 - Hoist Drum with Gearbox

4.5.2 Input Sleeve/Spline Connection

The power transfer between motor and gearbox is usually done by a so-called spline, a shaft-hub connection to transfer torsion. The shaft is externally splined and the hub is internally splined. This connection has multiple contacts between internal and external gearing, with the torque transmitted by the tooth flanks. Spline connections may also be used internally in the gearbox. The figure shows typical profiles for such connections.

⚠ Excessive wear of spline connections may cause a disruption of the connection, as a consequence suspended loads may be dropped when the motor is activated and the mechanical holding brake is automatically disengaged!

Wear of spline connections at the input sleeve is not visible to the outside, thus a dedicated inspection is recommended, see B.4 - Wear at the Power Input Sleeve (spline).

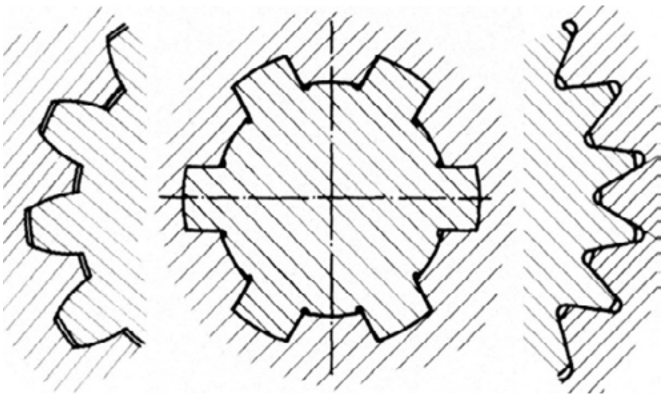


Figure 3 - Profiles of Shaft-Hub Connections

4.5.3 Holding Brake, Brake Linings

Winches of mobile cranes may use hydraulic brake valves as dynamic brakes and multi-disk brakes as holding brakes. Whilst the hydraulic brake is free of any wear, a holding brake suffers over time from little wear at the very last moment of dynamic braking and/or being active when the motion (hoisting, luffing) is initiated. Thus, the wear of holding brakes needs to be assessed, at least by performing regular tests of the braking performance, see Annex B.5 - Check brake performance and directional free-wheel brake (if equipped).

The holding brake is usually designed as a (multiple) disk brake consisting of disks alternatingly connected (directly or indirectly) to the input sleeve and the housing. The brake linings can be at the surface of some of the disks or separate and can be of different materials, e.g. organic, sinter material or paper. The disk package is pressed together by means of springs. Without hydraulic pressure acting against the springs the holding brake is automatically closed.

⚠ By design requirements of international standards holding brakes are required to withstand a single emergency braking only as separate inspection is required after the extraordinary event of emergency braking.

4.5.4 Wear of Bearings, Gears

Bearings and gears may suffer from wear which may influence the proper operation of the gearbox. This wear will usually become visible in regular oil analysis and may be noticed by an audible check.

4.5.5 Fatigue of Gears (Teeth)

In addition to wear the gear teeth are subjected to cyclic loadings (bending at foot of tooth) which may cause fatigue, see 4.3.

⚠ Fatigue of gears is not visible to the naked eye and cannot be detected in oil samples or by non-destructive testing, it requires monitoring the usage of the winch by comparing accumulated usage (service life) with design life, see Annex A.3 - Calculation of spent Share of theoretical Lifetime.

4.5.6 Oil

In the design of winches, the steel structure and the gear mechanism itself is an important part of the assembly. Special attention should be given to the lubricant to ensure the device is working as intended. Only oils specified by the manufacturer should be used. Some brakes require oil as well, that could be different from the gearbox. This vital component reduces friction between gears and bearings, prevents corrosion, transfers heat from gears, reduces the sound, removes and disperses contamination from the gears and mechanisms.
Oil is an important component for the seal to lubricate and to cool the sealing lip, preventing leakage of oil or ingress of water and other contaminants.
See Annex C – Oil specification and Handling for information related to Lubricants.

4.5.7 Oil Analysis

Oil analysis is to be carried out by a professional laboratory. The records will be reviewed on wear metals, contamination etc. The analyses are commented according to the data and information provided by the user. The more precise the information on the use of the oil, duration of use and the conditions of use, the more meaningful and targeted the preventive measures can be as a result.

A reliable diagnosis can only be made by a professional laboratory. Extremely high results in the analysis must not necessarily be equated with incipient damage.
In the overall assessment of the laboratory technician, all the values determined are considered in the correct classification based on their experience. Oil analyses, carried out at regular intervals, allow a more precise wear value or conclusions to be drawn about incipient damage to a specific component.
Each gearbox has its own wear behavior depending on its operating conditions.

4.5.8 Sealings

Sealings of gearboxes may suffer i.e., by high temperatures, wear out due to use (rotating shafts), wrong oil type and may deteriorate over time (getting more brittle when getting older), thus regular checks for leakages are recommended.

4.5.9 Housing

Housings of gearbox may be made of “monolithic” housings or may consist of several units being bolted together by mean of tensioned screws.
A thorough check of the status of such connections by observing potential paint cracks is recommended.

Note: It may be necessary to pull out the gearbox from the drum to execute such check.

4.5.10 Drum

The drum of the winch, usually a cast component, will suffer from abrasion by the comparatively hard rope. The wear will happen mainly at the wedges for climbing at the flanges of the drum.
A functional check of the winch will detect irregularities here and will reveal issues with the rope spooling on the winch, see Annex B.3 - Functional Checks.

4.5.11 Lowering Limiter

The lowering limiter ensures that a required number of rope turns is kept on the winch to safely transfer the rope pull onto the winch by means of friction. To ensure the function a regular test is required, see Annex B.3 - Functional Checks.

4.6 Assessing the Status of a Gearbox

4.6.1 General

For the purpose of this guidance, a winch is considered as an assembly of drum, gearbox, brake[5], hydraulic motor, valves and hoses/tubes. The gearbox is considered as a “black box”, a technical system with details about its design and internal functionality unknown to crane manufacturer and crane user.

This “black box” is described by a number of attributes (e.g., max. torque, max. revolutions, load spectrum, environmental conditions for operation and storage, oil to be used) and by its theoretical lifetime (design life) in connection to the classification (see Annex A.1 - General) of the particular winch, which follows ISO and FEM. Whether the theoretical lifetime can be reached depends on use and inspections/maintenance of the gearbox. This lifetime is only achieved when the gearbox is used and maintained as intended and stipulated in the instructions.

[5] The brake may be part of the gearbox or can be a separate item.

4.6.2 Inspections

Figure 4 - 3-legged stool

An assessment of a winch requires three major areas to be covered:
A - the determination of the remaining lifetime of the gearbox,
B - inspections and functional checks of the winch, and
C - taking and analysing and reviewing oil samples.

⚠ Only by combining these three elements similar to the three legs of a stool, a safe and reliable operation can be ensured.

The assessment of the gearbox to evaluate its ability to work properly over the next inspection period is thus done by:

A Calculation of the remaining lifetime of the gearbox (see 4.7 and Annex A – Calculating the remaining Lifetime)
B1 Visual check for abnormalities, in particular leakages
B2 Audible check for abnormal noise
B3 Review of wear at the power input sleeve (spline)
B4 Check of brake, braking performance and of directional free-wheel brake (if equipped)

To monitor the wear status of the gearbox during use, and to ensure the required quality of the oil, the checks mentioned above are accompanied with:

C Regular complementary oil analysis and the assessment of their results.

The actions under item B1) and B2) are considered part of the daily routine checks and included in any regular assessment.

4.7 Calculation of the theoretically remaining Lifetime of a Gearbox

For each winch the remaining lifetime of the gearbox must be determined regularly. If the end of design life is reached, the gearbox shall not be used further until a general overhaul has been carried out and a new design life (-time) has been established after repairs or exchange of components as needed.

The procedures of calculating the remaining lifetime and of proper documentation are described below, see Annex A – Calculating the remaining Lifetime.

4.8 Records of Checks, Inspection, Maintenance and Use,

All inspection/check findings need to be recorded in a log-book; the operator/user is responsible for recording. Identified defects or anomalies need to be assessed whether a safe execution of work is possible, if not the crane shall be retained from service until the issue is fixed. A competent person shall be informed and involved in the assessment, in case of doubt the manufacturer should be contacted.

Information on recording of the use and the determination of remaining lifetime is given in Annex A – Calculating the remaining Lifetime.

5. CHECKS AND INSPECTIONS

5.1 General/Frequency of Checks and Inspections

Checks (daily and weekly) are routine controls usually carried out by the operator. Inspections are carried out by maintenance personnel or other competent persons.
The general content for checks and inspections is described below, their frequency is described in the instructions of the crane, and may fall under national legislation. If information on timing is missing, the table in Annex E – Intervals for Checks and Inspections gives guidance for appropriate frequency/periods should be used.

A general overhaul after 10 years, if stipulated in the instructions, may be skipped if the provisions of this Guidance are followed.

Note: Regular oil analysis and keeping oil properties as intended, may elongate the exchange intervals which otherwise are based on hourly use, with the operating hours of the winch and not the engine hours being decisive.

5.2 Regular Checks

5.2.1 General

Outcome of checks, maintenance and inspections shall be documented. Events, such as overload or incidents during use, should be reported directly to supervisor responsible person and recorded in the crane logbook. They may require an extraordinary inspection.

5.2.2 Daily checks

Before commencing operation, a walk around with checking the equipment shall be performed to avoid damages and incidents. These checks are visual and by ear or feeling of the operator and recorded in the log-book.

5.2.3 Weekly Checks

Typical weekly checks of winches include the daily checks from above plus oil level checks, check of bolt connections as well as visual checks of the condition of unused winches, etc.

5.3 Inspections and Maintenance

Maintenance and inspections are performed by competent persons, carrying out visual inspections, operational inspections, taking oil samples, carrying out pressure checks, etc. Information about these tasks can be found in the manufacturer's instructions. If missing, recommendation can be found in Annex B – Checks, Inspections and Maintenance of this document.

5.3.1 Inspections as stipulated in the documentation

These tasks are recurring based on the maintenance schedule as per manufacturer documentation.

5.3.2 Annual inspections

Annual inspections[6] are performed by a competent person performing a visual inspection, performing a load test and reviewing records of (crane) log-book.

5.4 End of Service Life

A general overhaul or exchange is required at the end of the service life of winches/gearboxes and only executed by a competent technician following gearbox manufacturers guidelines or by the manufacturer.

Note 1: Most gearbox manufacturers offer trainings about maintenance and inspections.

Note 2: Most gearbox manufacturers offer a re-manufacturing or exchange program through the crane manufacturer.

Note 3: After the occurrence of an extraordinary event creating unusual conditions which may have impacted the performance a general overhaul may be necessary as deemed by a competent person.

[6] At least executed once per 12 months, local legislation or law might have no or more frequent inspections required.

ANNEXES

A – CALCULATING THE REMAINING LIFETIME

A.1 - General

Depending on the crane and its equipment there are different methods to register operating hours of a winch and to calculate the remaining lifetime.

a) No individual hour meter per winch
b) Individual hour meter for each winch
c) Automatic determination of remaining or used lifetime

Check plausibility of the records from last year e.g., check (crane) log-book, have defects detected been repaired/removed, determine remaining lifetime from records kept after deducting usage of recent period. The calculation method is shown below to explain the approach and is described in the crane manual.

If the remaining lifetime of the winch is very small or not sufficient for the expected usage in the next period, the user and the owner need to be notified and the finding shall be recorded in the log-book and inspection report.

Note: In some cases, an additional, intermediate inspection with determination of remaining lifetime, e.g., at 50% of the usual period, may allow further safe use up to that point.

A.2 - Assumed Operating Conditions

The designer assumes certain operating conditions when dimensioning and choosing the winches for the crane. Their classification, according to international standards and guidelines, (e.g., ISO 4301-1, FEM 1.001) is given in the crane logbook (see example in Annex A.4 - Documentation per Winch). The following parameters describe the classification for each winch:

- Classification mechanism: M1...M8
- Load collective: light; medium; heavy, very heavy
- Factor of the load collective: km = (0,125; 0,25; 0,5; 1)
- Theoretical service life: D = 100 ... 100000 h

A.3 - Calculation of spent Share of theoretical Lifetime

To calculate the spent share of the theoretical service life of the winches, the **actual operating conditions** (load spectrum) and the **operating hours** of the winches per inspection interval must be determined.

Only for winches without separate hour meter, the operating hours must be determined from records of engine hours. As a rule of thumb, the figures in the table below can be applied.

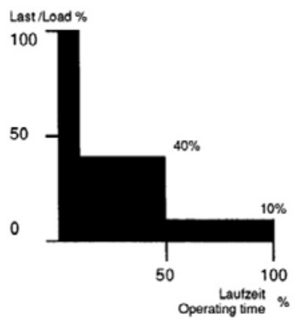
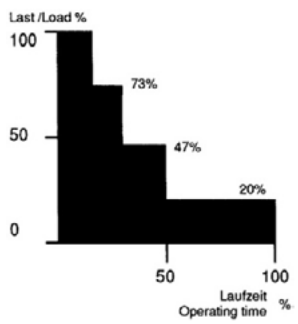
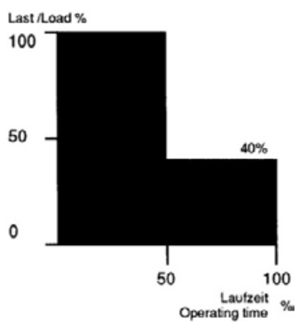
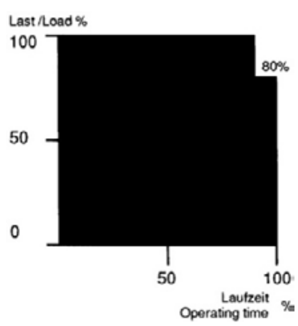
These factors are a guidance only, they shall be replaced with exact recordings if available or may be calculated for different percentages (higher/lower), if evidence is available that certain typical usages relate to other percentages.

Engine used for	Hoist winch	Luffing winch
Crane movements only	20%	5%
Crane + Travel on crawlers	20%	5%
Crane + Travel on Wheels	12%	5%

Table 1 - Factors to estimate winch usage

a) Determining the Operating Conditions (Load Spectrum)

1) From knowledge of the actual operating conditions, select the appropriate class of the load spectrum for the winch from the list below (see ISO 4301-1, FEM 1.001).
2) Enter the selected load spectrum in the crane examination log book for the respective inspection interval.

	**Load spectrum class:** light Q 1 L 1
	Power units or parts thereof subject to highest load only as an exception but which are routinely subject to very low operational demands
	Shares of operating time: - 10 % of the run time with highest load (dead load + 1/1 payload) - 40 % of the run time with dead load + 1/3 payload - 50 % of the run time only with dead load
	Load spectrum factor (Km): 0,125
	**Load spectrum class:** medium Q 2 L 2:
	Power units or parts thereof subject to highest load quite often but routinely only subject to low operational demands
	Shares of operating time: - 1/6 of the run time with highest load (dead load + 1/1 payload) - 1/6 of the run time with dead load + 2/3 payload - 1/6 of the run time with dead load + 1/3 payload - 50 % of the run time only with dead load
	Load spectrum factor (Km): 0,25
	**Load spectrum class:** heavy Q 3 L 3:
	Power units or parts thereof often subject to highest load and routinely subject to medium operational demands
	Shares of operating time: - 50 % of the run time with highest load (dead load + 1/1 payload) - 50 % of the run time only with dead load
	Load spectrum factor (Km): 0,5
	**Load spectrum class:** very heavy Q 4 L 4
	Power units or parts thereof regularly subject to high load in the realm of highest operational demands
	Shares of operating time: - 90 % of the run time with highest load (dead load + 1/1 payload) - 10 % of the run time only with dead load
	Load spectrum factor (Km): 1

b) Operating Hours of a Hoist per Inspection Interval

1. Calculate the effective operating hours per inspection interval (Ti)[7].
2. Record these hours for the respective inspection interval in the crane examination log book.

[7] Preferably the operating hours per winch are determined by separate hour meter or by the control system of the crane. If such information is not available the operating hours must be estimated.

c) Determining the Spent Share of the Theoretical Lifetime of the Winches

For the inspection interval i (typically 1 year in accordance with ISO 9927–1), the spent share of the theoretical lifetime of the winches is calculated from the formula:

$$S_i = \frac{km_i}{km} \times T_i$$

with:

- S_i = spent share of theoretical service life
- km_i = actual factor of load spectrum in the interval "i" in accordance with 9.1.3.a)
- km = design factor of the spectrum given in the documentation (here km = 0.125)
- T_i = effective operating hours in the interval "i" in accordance with 9.1.3.b)

This spent share is subtracted from the remaining theoretical service life after each inspection interval (see following example). Observe the following:

- **If the theoretical service life remaining** is presumably **insufficient** for the next operating period, a **general overhaul of the winch** must be carried out.
- If the theoretical **service life D is reached**, the winch may only be operated further **after** a **general overhaul** has been carried out.

If the theoretical remaining service life time is nearly consumed in comparison to the expected use (hours and load spectrum) for the next period additional intermediate determination of the used amount of service life is recommended. Advanced planning of the general overhaul is recommended as well.

A.4 - Documentation per Winch

The following figures show an example of the table for documentation which is delivered with the crane. Figure 5 identifies the winch gearbox and gives its classification, figure 6 (table) is intended for the documentation. In the first line the initial commissioning date with the theoretical service design life needs to be listed, the following lines are used for the records of periodic inspections per each gearbox.

The operator is responsible for documenting how the spent share of the theoretical service life for the winches has been calculated. The forms required for this purpose are enclosed in the examination log book for the crane. The theoretical remaining service life of each winch must be documented using these tables.

The crane user is responsible for the correctness of the information!

COMPANY NAME
COMPANY LOGO

Überwachung der Winden
Monitoring the winches
Surveillance des treuils

Tabelle zur Ermittlung der verbleibenden theoretischen Nutzungsdauer an Winde: Table for determining the theoretical remaining service life for winch: *Tableau de détermination de la durée d'utilisation théorique restante du treuil:*	
Krantyp: Crane type: *Type de la grue :*	KMHK 923
Baunummer: Construction number: *Numéro de construction:*	23929
Erste Inbetriebnahme: Initial commissioning: *Première mise en service:*	21 September 2023
Seriennummer des Windengetriebes gemäß Typschild: Serial number of winchgear as per serial plate: *Numéro de série du réducteur de treuil conforme à la plaque de type:*	123456/8

Auslegungsdaten der Winde Design specifications of winch *Données techniques du treuil*	
Triebwerksgruppe: Power unit group: *Groupe d'entraînement:*	*M1*
Lastkollektiv: Load spectrum: *Collectif des charges:*	*Q (L 1)*
Faktor des Lastkollektivs: Load spectrum factor: *Facteur du collectif des charges:*	*km = 0,125*
Theoretische Nutzungsdauer: Theoretical service life: *Durée d'utilisation théorique:*	*D = 3200 h*

weitere Erläuterungen siehe Schmier- und Wartungsanleitung des Oberwagens
For further notes, see the Lubrication and Maintenance Instructions for the Superstructure
Pour des informations plus détaillées se reporter au manuel de lubrification et d'entretien de la superstructure

Figure 5 - Information about the Winch

COMPANY NAME
COMPANY LOGO

Überwachung der Winden
Monitoring the winches
Surveillance des treuils

Inspektion Nr. Inspection No. *No. de l'inspection* "i"	Datum der Erstinbetriebnahme/ Datum der Inspektion Date of initial commissioning / date of inspection *Date de la première mise en service/ Date de l'inspection*	Betriebsbedingungen seit letzter Inspektion (Lastkollektiv) Operating conditions since last inspection (load spectrum) *Conditions de service depuis la dernière inspection (collectif des charges)*	Faktor des Lastkollektivs Load spectrum Factor *Facteur du collectif des charges* Km_i	Betriebsstunden des gesamten Krans Operating hours elapsed for the entire crane *Heures de service de la grue complète* [h]	Betriebsstunden des Oberwagens Operating hours elapsed for the superstructure *Heures de service de la superstructure* [h]	Betriebsstunden des Oberwagens seit letzter Inspektion Operating hours elapsed for the superstructure since last inspection *Heures de service de la superstructure depuis la dernière inspection* [h]	Betriebsstunden der Winde Operating hours elapsed for the winch *Heures de service du treuil* [h]	Betriebsstunden der Winde seit letzter Inspektion T_i Operating hours elapsed for the winch since last inspection, T_i *Heures de service du treuil depuis la dernière inspection* T_i [h]	verbrauchter Anteil der theoretischen Nutzungsdauer S_i Spent share of the theoretical service life, S_i *Partie utilisée de la durée d'utilisation théorique* S_i $S_i = Km_i / Km * T_i$ [h]	verbleibende theoretische Nutzungsdauer Theoretical remaining service life *Durée d'utilisation théorique restante* $D_i = D_{i-1} - S_i$ [h]	Name des Prüfers Name of Inspector *Nom de l'inspecteur*	Unterschrift Signed Signature	Bemerkungen Notes Remarques

S_i = verbrauchter Anteil der theoretischen Nutzungsdauer seit der letzten Inspektion / Spent share of theoretical service life since last inspection / *Partie utilisée de la durée d'utilisation théorique depuis la dernière inspection*
D_i = verbleibende theoretische Nutzungsdauer / Theoretical remaining service life / *Durée d'utilisation théorique restante*
D_{i-1} = verbleibende theoretische Nutzungsdauer nach der vorhergehenden Inspektion / Theoretical remaining service life after previous inspection / *Durée d'utilisation théorique restante après la dernière inspection*
Km = Faktor des Lastkollektivs der bei der Berechnung der Winde zu Grunde gelegt wurde / Load spectrum factor which formed the basis of calculation for the winch / *Facteur du collectif des charges servant de référence pour le calcul du treuil*
Dieser Faktor ist dem Kranpaß zu entnehmen / This factor must be taken from the crane certification log / *Ce facteur est à prélever du carnet de la grue*
Km_i = Faktor des Lastkollektivs im Inspektionsintervall "i" / Load spectrum factor for inspection interval "i" / *Facteur du collectif des charges pour l'intervalle d'inspection "i"*
T_i = effektive Betriebsstunden im Inspektionsintervall "i" / Effective operating hours for inspection interval "i" / *Heures de service effectives pour l'intervalle d'inspection "i"*

Für die Richtigkeit der Angaben haftet der Betreiber! / The (crane) user is liable for the correctness of the information! / *L'exploitant est responsable pour la conformité des indications mentionnées !*

weitere Erläuterungen siehe Schmier- und Wartungsanleitung des Oberwagens
For further notes, see the Lubrication and Maintenance Instructions for the Superstructure
Pour des informations plus détaillées se reporter au manuel de lubrification et d'entretien de la superstructure

Figure 6 - Example Template for Documentation

A.5 – Example of a Calculation

Assuming a history of 3 inspection intervals, the following example shows the calculations to create the table if done manually.

Inspection no. 1 (year 1)

Values for the design load spectrum factor (here: **km = 0.125**) and the theoretical service life (here: **D = 3200h**) are specified in the head of the respective table (see example above).

In the 1st period the crane has been used for assembly work in 2 shifts in the past year:

Load spectrum **L1**, i. e. **km_1 = 0.125**
The operating hour meter for the superstructure reads **800h**.
The winch was in operation for approx. 20 % of this time i. e. **T_1 = 160h**.

The used share **S_1** of the theoretical service life is therefore during 1st inspection:

S_1 = km_1 / km x T_1 = 0,125 / 0,125 x 160h = **160h**

Remaining theoretical service life after the first year:

D_1 = D – S_1 = 3200h – 160h = **3040h**

Inspection no. 2 (year 2)

The crane was heavily used for unloading operations at a harbor, with an estimated load spectrum **L3**, i. e. **km_2 = 0.5**. The operating hour meter for the superstructure reads now **2000h**, i.e., during this period the Crane was used for: 2000h − 800h (used in the first year of operation) = **1200h**.

The winch was in operation for approx. 40 % of this time i. e. **T_2 = 480h**.

The used share **S_2** of the theoretical service life is therefore in the 2nd inspection interval:

S_2 = km_2 / km x T_2 = 0,5 / 0,125 x 480h = **1920h**

Remaining theoretical service life after the second year:

D_2 = D_1 – S_2 = 3040h – 1920h = **1120h**

Inspection no. 3 (year 3)

The crane was used for assembly work and occasionally used for unloading work in a harbor, estimated load spectrum **L2**, i. e. **km_3 = 0.25**.
The operating hour meter for the superstructure reads **3000h**, i.e., usage during this period is calculated as: 3000h − 2000h (2000h used in the first two years of operation) = **1000 h**.
The winch was in operation for approx. 30 % of this time i. e. **T_3 = 300 h**.

The used share **S_3** of the theoretical service life is therefore in the 3rd inspection interval:

S_3 = km_3 / km x T_3 = 0,25 / 0,125 x 300h = **600h**

Remaining theoretical service life after the third year:

D_3 = D_2 – S_3 = 1120h – 600h = **520h**

Calculations must now be carried out to determine whether the remaining theoretical service life is sufficient for the next operating period. If this is not the case, a general overhaul must be carried out.

A.6 - Documentation

The documentation can be done either by manually calculating of the data and filling in the table usually provided with the instructions for the crane or by using a spreadsheet programmed for this purpose. An example of such spreadsheet is provided by ESTA and can be downloaded from the library (https://estaeurope.eu/library/); the following figure shows the example from above in the form created by this spreadsheet:

Remaining service life winches

Crane type :	All Terrain 300t
Serial number :	123456
Park number :	-
First date in service :	01.10.2020
Winch name	Hoist 1
Winch Type	Hoist winch
Serial number :	9876
Drive gear group :	M3 (1 Bm)
Load Spectrum :	Q1/L1
Factor of Load Spectrum (Km) :	0,125
Theoretical servicelife (h) :	3200
Effective operating hours are measured with:	C :

A : Operating hour meter installed on Winch
B : Operating hour meter installed for total superstructure
C : Operating hour meter is used for both crane engine and crane drive
D : No operating hour meter is installed

Nr.	Date of initial service / Date of inspection (dd-mm-yyyy)	Operating conditions since last inspection (Load Spectrum)	Factor of Load Spectrum since last inspection (Kmi)	Total operating hours (h)	Percentage of winch use (%)	Operating hours since last inspection (h)	Operating hours of winch since last inspection (h)	Used part of Theoretical service life (h)	Remaining Theoretical service life (h)	Name of inspector	Remarks
0	01.10.2020								3200		
1	30.09.2021	Q1/L1	0,125	800	12,0	800	96	96	3104		
2	16.10.2022	Q3/L3	0,5	2000	12,0	1200	144	576	2528		
3	01.10.2023	Q2/L2	0,25	3000	12,0	1000	120	240	2288		

Figure 7 - Example Spreadsheet

Using the spreadsheet

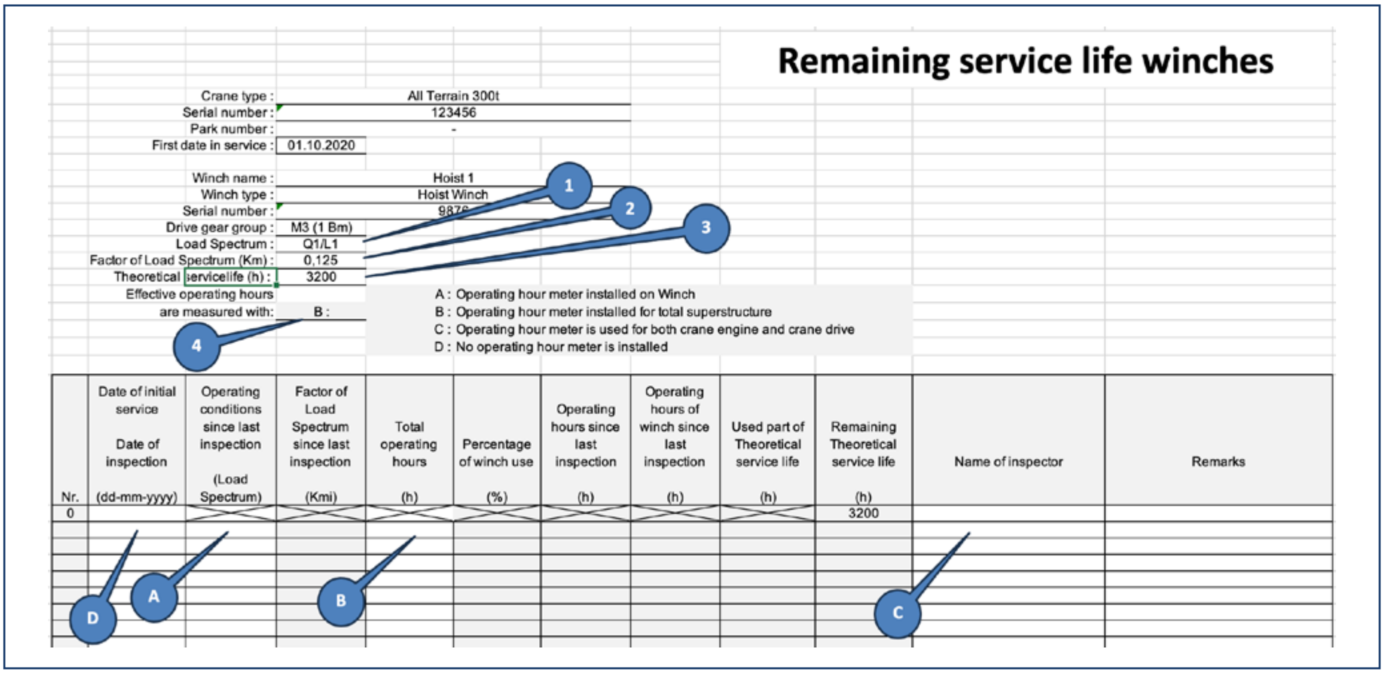


Figure 8 – Information needed for Input

Prior to a first calculation the header information needs to be completed, important information for the following calculation is the "Load spectrum" (1), the "Factor of Load Spectrum" (2) and the "Theoretical service life" (3), all of them to be found in the documentation of the crane, furthermore the method of measuring the operating hours need to be indicated (4).

For each calculation the spreadsheet needs as input the "operating conditions since last inspection" (A), "the total operating hours" (B) to calculate the remaining theoretical lifetime. The record is completed by the name of the inspector(C) and the date of inspection (D). The spreadsheet can easily be adapted to the needs of each company.

B – CHECKS, INSPECTIONS AND MAINTENANCE

B.1 - Safety during Checks, Inspections and Maintenance

Winches and their components are usually located high on top of the machine and working under high pressures.

While working on this equipment, be alert for and mitigate at least the risks of:

- High hydraulic oil pressure,
- High temperatures of oil and components,
- Spring tension of brake components,
- Tension on hoist cable,
- Heavy components,
- Slippery surfaces due to oil (leaks),
- Risk of entrapment,
- Risks of working at height.

B.2 - Visual Checks

Visual checks are considered checks using your senses.

- Check for leaks of oil; is there any excess grease/oil to be found and are there any particles in that excess material?
- Cracked or discoloured paint,
- Crack in paint on body of gearboxes at connecting points
- Loose bolts, in particular rust trails from bolts,
- Wear of drum,
- Mechanical damages at the drum
- Wire rope condition & spooling
- Grinding marks on side wall of drum
- Loose fittings at hydraulic connections
- Check breathers (unclogged, and desiccants still okay),
- Check all hydraulic hoses of the winch – see FEM 5.020 (see Annex G – Bibliography) as guidance

B.3 - Functional Checks

Run the winch at different speeds, loaded/unloaded and listen for any unusual, strange or abnormal grinding noise of bearings, 'cloink' sounds from loose bolts and/or bearings.

Operate the winch and observe the spooling of the rope, observe the moment when the rope changes layers to detect worn-out rope climbing aids (aka riser) at drum flanges, check for other difficulties when spooling the rope, e.g. caused by wrong rope diameter.

The lowering limiter is to be checked by spooling off the rope until the remaining safety windings are reached. The lowering limiter irrespective of its design shall switch off the lowering movement immediately. Dysfunctional lowering limiters require immediate repair or adjustment, the equipment shall be taken out of service until the problem is fixed.

B.4 - Wear at the Power Input Sleeve (spline)

In the figures below, a new spline (external teeth) at the output shaft of a hydraulic motor is shown in fig. 9. The teeth of the connection to the gearbox carry the complete motor torque whilst turning at high revolutions (up to around 5500 rpm). These teeth (both sides) are subject to wear and require checking. The picture in fig. 10 shows a worn-out motor spline, the picture in fig. 11 the corresponding hub (input sleeve), both parts were beyond acceptable wear limits and needed exchange!

Figure 9 - New spline at motor

Figure 10 - Motor spline worn out

Figure 11 - Spline at hub worn out

⚠ Excessive wear of spline connections may cause a disruption of the connection, as a consequence suspended loads may be dropped when the motor is activated and the mechanical holding brake is automatically disengaged!

Wear of splines at the power input sleeve will be visible only by visual inspection after removing the hydraulic motor. Unless stated differently by OEM or gearbox manufacturer, the splines inside of the gearbox (i.e., "behind the sealings") are lubricated by the oil in the gearbox, excessive wear will become visible in the oil analysis.

To inspect the connection between hydraulic motor and gearbox take the hydraulic motor from the gearbox and clean the area in particular the surfaces which transfer the torque. Check contact surfaces for wear or abnormalities. If the limits given by the gearbox or crane manufacturer are reached or it is assumed that they will be reached during the next period of operation, the motor-gearbox combination needs to be repaired/ exchanged, the crane winch may not be operated until the connection is fixed.

In case no values are given by the manufacturer, in the crane documentation or the documentation for the gearbox related to wear, the indication of Figure 12 can be used.

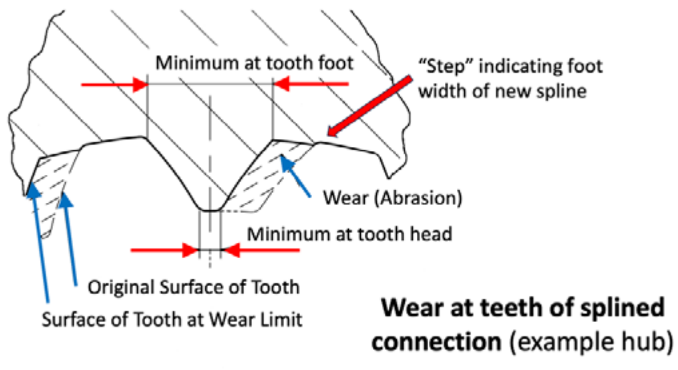
event. A holding brake shall be inspected by competent personnel of the gearbox manufacturer or OEM after such incident.

Note: The correct function of the dynamic brake and the holding brake shall be tested after each maintenance of the brake system of a winch; such functional tests are recommended as well after longer-out-of-service periods. Such tests comprise, but may not be limited to
1) activation (opening and closing) of holding brake,
2) dynamic braking of the hydraulic brake and
3) correct function of holding brake.

Test the performance of a holding brake by using:

- **a.** the crane test procedure as given, or
- **b.** with 100% of the line pull capacity with the hoist rope at the highest layer of the winch (short boom and small number of reevings) by lifting a load, just above ground and hoover for 15 minutes,
- **c.** observe whether creeping of the holding brake occurs e.g., by a reference point placed on the drum.

⚠ Using 100% of line pull requires proper pre-tension and spooling of the wire rope.



Where any wear becomes visible on the spline(s) both components of the coupling shall be replaced.

Indication of wear is visible as a tiny step as shown in the figure.

Figure 12 - Determination of Wear at Spline

Various lubrication designs are used on spline connections. When re-assembling the connection this must be observed. Oil-less systems should be lubricated with grease, oil-filled connections should be pre-lubricated with oil. In no case the connection shall be dry!

B.5 - Check brake performance and directional free-wheel brake (if equipped)

The mechanical brakes combined with gearboxes on mobile cranes are holding brakes. The dynamic braking is done by the hydraulic system. The holding brake with a proper adjusted and functioning activation will suffer from little wear only. Nevertheless, the holding brakes shall be tested according to the inspection scheme in Table 4 - Intervals for Checks and Inspections, at least once per year.

⚠ In case of an emergency (e.g., problems in the hydraulics), the holding brake will serve as emergency brake to restrict movements of the load and stop a lowering load after a short distance. Holding brakes are designed to take one emergency braking only, as the brake linings will suffer from such

B.6 – Test of brake function

The holding brake and the brake activation shall be tested according to procedures given in the instructions. If no intervals for inspection of the brake are mentioned in the instructions, information can be found in Annex E – Intervals for Checks and Inspections, table 4.

⚠ A dis-assembly of the brake mechanism itself is NOT recommended as only competent persons with special knowhow and experience are able to conduct such work.

⚠ The correct function of the holding brake is key for safe operation of the crane. If in any doubt consult the crane or component manufacturer.

If the holding brake fails, or is not activated correctly, the complete unit (input sleeve with brake linings, springs and hydraulic activation) shall be exchanged.

Note: Whereas hydraulically driven winches are usually brought to stop by the brake valve before the mechanical brake is applied, mechanical brakes on electrically driven winches bring the winch to the final stop; as such and *with the high inertia of the electric motor they are subject to more wear. Specific provisions for brake wear check on electrically driven winches are not covered in this document. Adhere to the recommendations form the OEMs instructions and/or contact the OEM.*

B.7 - Maintenance

Following the maintenance intervals as given by the manufacturer, the following (visual) checks should be executed considered where applicable (the list may not be exhaustive):

- Visual check of oil quality – level, colour, odour,
- Take an oil sample for analysis in the laboratory (see Annex D – Oil Analysis),
- Top up oil with designated lubricant, (check oil level)
- Clean / replace breather(s)
- Check the tightness of bolts.
- Change oil of gearbox with designated lubricant (if required). Check oil level as there might be more compartments – gearbox and brake system
- Change holding brake oil (no need for analysis)
- Pressure checks of holding brake
- Lubricate V-ring / seals / support
- Inspect drive / spline shaft for wear
- Review condition and installation of hoses, see FEM 5.020 (see Annex G – Bibliography) as guidance
- Check accumulator pressures
- Grease counter-bearing

C – OIL SPECIFICATION AND HANDLING

In the lubricants overview of the equipment and/or gearbox manufacturer you find the list of released oils for the winch gearboxes and brake systems. Using the correct oils are key to ensure the functions of its vital components.

Gear oils can be classified in base oil types Mineral and Synthetic. Both perform well in most applications. However, mixing a mineral oil with a synthetic oil (PAG with PAO) or mixing synthetic oils will affect the characteristics and might result in premature wear of the structure and/or damage the seals. Mixing can also result in sludge (additive depletion) in the system caused by incompatibility reactions of the lubricants.

⚠ Using a clear marking system on the component referring to the oil to be used, is supporting the use of correct oil in the component (e.g.: blue dot means Mineral ISO 220 oil, red dot means PAG 220…).

Oil can speak – you may understand the status of the gearbox and the status of the lubricant, you only need to listen carefully. Proper handling of oil – besides the correct choice of type – requires to:

- Keep the oil **cool** during use, increase of oil temperature during use significantly decreases the service life of the oil,
- Keep it **clean** at all times, with special attention during oil exchange and topping up to avoid ingress of contaminants,
- Keep it **dry** by avoiding water ingress into stored oil and during exchange and use.

- Store drums with new oil inside of buildings and place a breather on the drum.
- Always use clean equipment when handling oil, e.g. clean funnel when topping up oil in gearboxes.

D – OIL ANALYSIS

D.1 - General

Oil analysis is used to monitor the condition of the inside of the gearbox without opening the device. The analysis can inform you about the physicochemical properties of the oil, state of the additive package and contaminants. Contamination can have external or internal reasons.
If resulting from internal reasons contamination is indicating internal wear of gears, bearings or brake linings etc. Condition monitoring and diagnosis of systems is according ISO 14830-1:2019

⚠ Oil analysis does not provide information about potential fatigue of elements of a gearbox!

Reviewing oil on a frequent basis could change the maintenance strategy and extend the oil life reducing the burden on the environment and saving cost, especially on larger gearboxes containing large volumes of oil.

D.2 - Preparation & taking the Sample

Oil analysis does not start with the laboratory, it starts with taking a proper sample and providing the laboratory with accurate information about the oil and the application.

⚠ It is important to take a clean and proper sample that represents the oil of the component without contaminants from external sources. This process is according to ISO 14830-1:2019.

⚠ Take attention to the manufacturers safety recommendations when taking a sample.

1. Run the gearbox prior to taking any sample to warm up the oil and get a good mix of the oil in the system.
2. Do not take samples immediately after shut down, allow the particles to distribute evenly in the lubricant but take the sample within 15 minutes of the machine being shut down.
3. Remove contamination from sample point and ensure that the used equipment for taking the sample is clean prior taking the sample.
4. Use dedicated sample bottles, manual sample pump and tubing provided by the laboratory.
5. Always use a new piece of sample tubing which is flexible, clear and plastic derived material, compatible with chemicals and temperatures, cut the end of the hose at a 45° angle.
6. Take an oil sample, the preferred method is to use a dedicated sample port, or use a dipstick tube or level glass to sample.
7. Always take the 1st amount of oil as waste oil to ensure a representative oil amount as 2nd sample. Use the fresh 2nd sample for testing, re-using the sample tube, but new bottle.
8. Dispose waste oil as per environmental requirements.
9. After sampling, top up the oil level with same oil as needed. Report to the laboratory the amount of added fresh oil.
10. Provide all necessary information per each sample via submission form or online application. Inform the laboratory about gearbox type and manufacturer, application and oil characteristics (type). Inform the laboratory about findings of the visual inspection such as low/high oil level, indications of leak or abnormal smell of the oil if observed.
11. Send the sample to the laboratory as soon as possible.

⚠ It is recommended to always use the same procedure and sample ports to warrant comparable samples to create a sample history of a winch gearbox.

D.3 - Carrying out the Oil analysis

The recommended tests to receive a complete report representing the internal condition of the gearbox are:

- Viscosity @ 40°C (ASTM D445, D7279)
- Viscosity @ 100°C (ASTM D445, D7279)
- Water by Karl Fischer (DIN 51777 or ASTM D6304 or DIN EN ISO 12937)
- Acid Number (TAN) (ISO 3771 or ASTM D664)
- Metal Elements ICP (ASTM D5185)
- Particle Count and size (ASTM D7647) and report according ISO4406
- PQ Index (ASTM D8184)
- FTIR (ASTM E2412)

⚠ The laboratory should use supplied specifications of the product manufacturer (component or equipment) evaluating the sample results related to particles, particle size and cleanliness[8].

With regard to a seamless history of oil analysis including the interpretation by the laboratory it is recommended to limit changes of laboratories.

D.4 – Guideline for limiting thresholds on samples

As a guideline for the laboratory the following limits can be used for hoist and luffing winches.
These gearboxes have a different use than other (drive) gearboxes in other applications and industries and require different limits.

The recommendations in Table 2 are calculated using the guidelines of ISO 14830:2019 table F.2 and are based upon more than 3600 samples of winch gearboxes.

[8] To be provided by Equipment manufacturer or use generic guidelines as per Table 2 - Limiting thresholds on samples.

				Recommended limits		
				Nominal	Warning	Severe
Wear Metals	Iron	Fe	ppm	41-249	250-300	> 300
	Chromium	Cr	ppm	1-4	5-10	> 10
	Nickel	Ni	ppm	1-4	5-10	> 10
	Aluminum	Al	ppm	1-9	10-25	>25
	Copper	Cu	ppm	5-34	35-80	>80
	Lead	Pb	ppm	1-14	15-30	>30
	Tin	Sn	ppm	1-14	15-30	>30
	Cadmium	Cd	ppm	Observe trends and recommendations from laboratory.		
	Silver	Ag	ppm			
	Titanium	Ti	ppm			
	Vanadium	Va	ppm			
Cotaminant or Multi Source	Silicium	Si	ppm	New oil + 10	New oil + 30	New oil + 75
	Sodium	Na	ppm	1-4	5-10	>10
	Potassium	K	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Antimony	Sb	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Manganese	Mn	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
Additives	Boron	B	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Barium	Ba	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Calcium	Ca	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Magnesium	Mg	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Phosphorus	P	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Molybdenum	Mo	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Zinc	Zn	ppm	New Oil	New oil +/- 10%	New oil +/- 20%
	Particle Quantifier			45 - 199	200 - 300	>300
	Water by Karl Fischer		ppm	<100	100 - 500	>500
	Viscosity		CsT	new oil	New oil +/- 5%	New oil +/- 10%
	Cleanliness		4/6/14 µm	21/19/16	22/20/17	23/21/19
	Acid number		mgKOH/g	new oil	new oil +/- 50%	New oil +/- 75%

Table 2 - Limiting thresholds on samples

This table can be used as general guidance. Information from manufacturers and experience of the laboratories should be priority over this table.

Compare deviations with observation to the values of the new oil as delivered. It is recommended to determine the characteristics of new oil (baseline) by taking samples of new oil at least once per year. Always relate the results compared with the trend.

Recommended actions by colour:

Green: No recommendation, other than the comments on the report

Yellow: Resample after 2 months, if abnormal wear metal and/or cleanliness and/or PQ values are observed

Red: Resample after 1 month, if critical values for wear metal and/or cleanliness and/or PQ values are observed

With 3 times reoccurring yellow or red on the same contaminants, it is recommended to contact the OEM or laboratory for further actions.

D.5 - Interpreting Oil analyses Results

The following table lists potential reasons for observations from the oil analysis; the list is not extensive and there may be other reasons, contact the laboratory asking for recommendation if further analysis seems necessary.

⚠ To reduce potential ingress of humidity into the gearbox with temperature changes due to operation and/or environment, breathers (if equipped) should be those which contain water-repelling membrane(s) and/or desiccant. Using such components will increase the lifetime of the oil and will support adequate lubrication between inspections.

Samples should be taken at least once per 1000 engine hours (representing approximately 200 gearbox hours) or once per year whatever comes first.

Use of the same laboratory for each sample is recommended to ensure the analysis and reporting are similar, and previous maintenance actions or comments taken in consideration.

Subject	Observation	Possible Reason	Solution
Viscosity	Deviation of Base line	Wrong product information provided to lab	Review product information and request review of report.
Viscosity	Too low	Wrong oil indication	Request revision of the report
	Too low	Lube mixture	Replace oil, resample; inspect for external leak from hydraulic motor or other components
	Too low	Lube mixture	Different oil added to top up
Viscosity	Too high	Oil mixed with water (see water content)	Inspect for leaks and Replace oil
	Too high	Lube mixture	Different oil added to top up
	Too high	Wrong oil indication	Request revision of the report
	Too high	Frequent overheating	See also acid number. Replace oil and monitor new reports
Particles	Metallurgic	Wear particles	Resample: Yellow: 2 months (200 engine hrs) Red: one month (100 engine hours)
	Organic / environmental materials	Wrong / missing breather	Replace breather and observe
Water	Water	missing breather, environment with high humidity	Check for water ingress / frequent changes
Acid number		Frequent overheating	Replace oil and monitor samples over time.

Table 3 - Observations and potential Reasons

D.6 - Recording Oil Analysis results

Oil sample reports shall be stored in a database with reference to the respective winch. Therefore, each winch should have a unique component identification. Using the unique component identification allows to monitor trends and to indicate the stage of wear of the component during its life cycle (see Annex F.2 - Wear).

E – INTERVALS FOR CHECKS AND INSPECTIONS

Intervals for checks and inspections shall be taken from the instructions of the manufacturer, or if missing, the intervals recommended in the following table shall be taken.

The general overhaul after 10 years, if stipulated in the instructions, may be skipped if the provisions of this Guidance are followed.

Description of check	Interval
Check for leaks	weekly
Check bolts and mounting (visual)	monthly
Check oil level	weekly
Oil analysis	every 1000 engine hours (representing approximately 200 gearbox operation hours) or annually
Change oil	based upon oil analysis report
Check brake function	Annual inspection
Functional test	Annual inspection
Calculate & record remaining lifetime	Annual inspection
Inspect drive sleeve (dry sleeves only)	Inspection after every 1000 operation hours of the gearbox
Inspect drive sleeve and replace brake unit	After emergency braking

Table 4 - Intervals for Checks and Inspections

F – COMPLEMENTARY INFORMATION

F.1 - Use of Gearboxes on Mobile Cranes

Mobile cranes typically use diesel hydraulic drives to create linear and rotary movements. The diesel engine operates a pump creating a flow of hydraulic oil with a certain pressure; this flow is distributed to cylinders and motors creating the intended movements. Hydraulic motors require a certain minimum number of revolutions to develop a steady movement, like the combustion engine in a car.

They operate better at higher revolutions and their turns need to be reduced by gearboxes if low revolutions are required. A reduction gearbox converts higher motor revolutions at lesser momentum into lesser revolutions at higher momentum. In e.g., a hoist winch, it is expected that the load can be lifted at very low but still evenly speeds.

On mobile cranes gearboxes are often inserted into the drum of the winch. Their design life corresponds with the typical use of the mobile crane, which itself has a limited lifetime. Mobile cranes and their winch gearboxes are designed according to international standards, with an assumed "standard use"; the classification of the crane and its drives is found in the operating instructions. If the actual use is less than the assumed one (i.e., lesser loads by number of lifts or usage of capacity in a given period) the crane structure and/or its drives will last longer than the average one and vice versa.

Gearboxes are subject to degradation and possibly destruction by fatigue and wear.

F.2 - Wear

There are several mechanisms of wear, which can occur alone or (even worse) in combination. Wear in gearboxes can be mitigated by the use of correct type and amount of oil and the care for the quality of the oil.

On gearboxes used in winches mainly the following types of wear are observed:

adhesive wear	transfer of material from one contact surface to the other
abrasive wear	abrasion of particles from one surface due to friction contact with another (grinding), particles deposed in wear debris in the oil
pittings	happens at bearings and gears, small particles breaking off during contact under pressure forming "pits"

The following figure shows the typical development of a wear rate over the time of use. A known threshold for max. wear rate is assumed (see figure). At the end of each interval a regular inspection including, but not limited to, oil analysis is done.

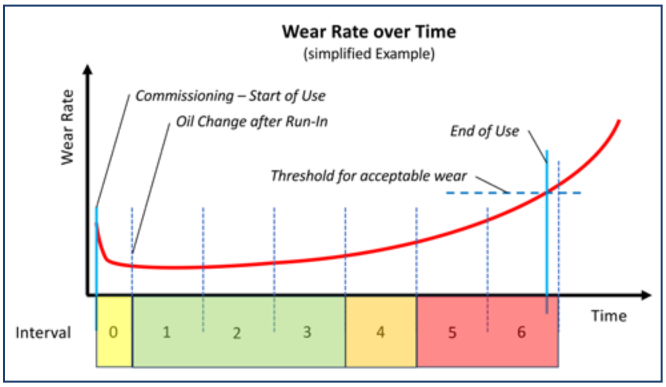


Figure 13 - Wear Rate

Interval (intervals are not equal to sample periods)

0 run-in phase directly after start of use, usually higher wear due to grading of the contact surfaces of components moving under contact pressure, often the reasoning for an "early" oil exchange to take out wear debris,
1 normal use, little wear only,
2 normal use, wear slightly increased,
3 normal use, wear level comparable to interval 2,
4 normal use, wear rate increasing,
5 continued use, wear rate further increasing, plan for countermeasures,
6 use ends during this interval, as wear is at threshold, to achieve max. duration of use whilst being on the safe side, the inspection interval may be shortened.

Wear particles found in oil samples can be analysed by type, size and amount and may give indication about the wear status. To interpret the status a "history of oil samples" is necessary as the trend of the wear rate is important to observe (compare figure above, intervals 1, 2 and 3 have similar wear rate increases, whereas interval 4 and in particular 5 show a significant change in growth).

F.3 - Fatigue

In materials science, fatigue is the initiation and propagation of cracks in a material due to cyclic loading. If the loads are above a certain threshold, microscopic cracks will begin e.g., at local stress concentrations such as imperfections, holes, or grain boundaries in metals. The crack will continue to grow until it reaches a critical size, starting rapid propagation followed typically by complete fracture of the structure. The stress values that cause fatigue damage are typically much less than the yield strength of the material.

The effect of fatigue is commonly known from paper clips, when bent a few times they break.

Figure 14 - Fatigue

The picture shows three identical paperclips, the one at the right has been bent 12 times before it failed.

Fatigue must not become visible, but from material science, testing and component calculation the lifetime limit can be determined as combination of cyclic loading at certain stress levels and load cycles – the result is one aspect of the so-called design life.

Fatigue resistant designs are possible, but require significantly stronger components (more structural resistance, bigger, increased wall thicknesses, etc.) or better material or even both. Fatigue resistant designs result in increased weight, space requirements and costs and are as such not feasible for the design of the parts and components related to crane operation.

Note: Parts and components for travel on roads may need to fulfil other design criteria.

G – BIBLIOGRAPHY

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H – SOURCES OF PICTURES

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