STANDARDISING THE DESIGN AND PRODUCTION OF MOORING WINCHES THROUGH MORE COHESIVE REGULATIONS: A NECESSARY STEP

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SUMMARY

Stricter guidelines, hand in hand with continuous technological advances, mean that vessels are safer and more efficient. At the same time, these changes make ships more complex and expensive. However, this is not the case with mooring equipment. Regulations vary in content, but have the same objective. They fail to improve the ships' safety and prices are negatively affected. A vessel's mooring system has to take into account various sets of regulations, including those of the country under whose flag it is sailing; the classification societies; ship owner associations and the terminal ports. This paper will analyse the contents of all these regulations in an attempt to find what they have in common. Its next purpose is to propose guidelines with unified contents. The proposal is to harmonise regulations that affect the mooring winch's operation, design and construction. With standardised regulations, it would be possible to carry out a single design process and one calculation for components. These steps will be apt for every kind of project. By unifying this process, the final price of manufacturing equipment will be reduced.

NOTATION

D	original diameter of the warp end
T	nominal mooring speed in KN
r	admissible variation in % of the line lifting speed
P	power of the mooring winch in w
l	length of the drum in mm.
L_c	length of the warp end in mm
L	length of the line to stow in m.
m	turn line numbers
M	warp end modulus
N_m	rpm of the engine
n	number of layers reeled in the drum
V_s	lifting speed in m/s.
η_t	stream ratio
d_i	interior diameter of the drum in mm
d_e	exterior diameter of the drum in mm
d_c	diameter of the line in mm
d_t	diameter of the work in split drums
K_e	stowage ratio in the drum

1. INTRODUCTION

When a vessel reaches the port, its propulsion system no longer operates. The vessel becomes subjected to the action of the currents and winds. To run the boat safely under these conditions, anchoring and mooring systems must be used. The latter system includes moorings to secure the vessel to land; components that are fixed to the deck- such as pedestal and other fairleads and bitts - and the mooring winch, which manipulates the ropes and cables.

Mooring winches play an important role as they have a dual purpose: to handle the lines during the manoeuvre and later to maintain them in the correct position while the ship is at port. Mooring of a boat must be adapted according to variations in its displacement or in response to changes in tidal conditions or currents. The manoeuvre can be carried out by making continuous manual adjustments over each rope. Alternatively it can be done automatically with a constant tension winch.

In terms of conventional winches, those with constant tension maintain the mooring rope's tension. This is an automatic process based on a pre-set variable. When the mooring rope tension exceeds a certain value, the drum rotates to release more rope. When the tension falls below the pre-set value, it hauls down the rope until it reaches a fixed tension. Table 1 is based on the contents of ISO 3730 [1]. It clarifies the functions of mooring winches, according to whether they are conventional or constant tension.

Table 1 – Functions of mooring winches based on ISO 3730

OPERATION	***Conventional mooring winch***	***Automatic or constant tension winch***
Mooring	By means of drum	
Stowage of mooring	In drum	
Maintaining tension through brake	In drum	
Warping	Optional by means of drum or warping end	
Maintaining tension through automatic devices	Not available	In drum

The flag and port states, as well as the ship owners and charterers, all have an influence on the legal framework to ensure vessels operate safely [2]. Within this framework, two types of measures come into play: state regulations, such as the International Standards Organisation (ISO) and UNE, the Spanish system, and international conventions from the International Maritime Organisation (IMO) and International Labour Organisations (ILO). On the other hand, owners and charterers have to juggle varying sets of regulations. Regulatory bodies in this sector include the Oil Companies International Marine Forum (OCIMF) and International Gas Tanker and Terminal Operators (SIGTTO). Another entity is the classification society chosen by the ship owner. Here, the regulations on winches from all these sources have been studied.

156 countries send representatives from their own standard-setting bodies to the ISO. Among these countries are most of the European states. Their practical guidelines have been developed with reference to the ISO – TC 8 Technical Committee on Shipbuilding and Marine Structure). ISO 3730 "Shipbuilding – Mooring Winches" [1] refers to designing and testing mooring winches, including their components. These documents inform this study.

Another document is provided by the Oil Companies International Marine Forum, whose mission is to promote maritime safety through by using tankers and terminals in a controlled way. To this end, a range of associations from this sector have formed a working group [3]. This group produced "*Mooring Equipment Guidelines – MEG3*", which establishes the basic principles of safe mooring [3].

Thanks to an increase in demand, shipping has evolved over the XX Century to take its place among the vanguard in the field of logistics. Economies of scale have been applied and ship registration has been liberalised. At the same time, transport systems- particularly those for ships and ports- have made strides as costs are continuously being reduced. That is why this sector enjoys a privileged position. [4]. As it continues being improved in the name of competitiveness, the shipping of the future will still need to have its operating costs reduced. This trend means that both ship building and running costs will continue to be lowered.

If the implementing regulations are standardised, the design and manufacture of mooring equipment will be standardised. The cost of building and operating vessels will be reduced in keeping with the needs of shipping.

2. COMPARING EXISTING REGULATIONS

Before one can compare the regulations, it is necessary to establish a series of definitions so that this comparison is homogeneous, as shown in Appendix 1.

Classification societies have sought to harmonise regulations through the International Association of Classification Societies (IACS) [5]. "*Requirements concerning mooring, anchoring and towing*-UAR2" establish conditions that the mooring lines (ropes and cables) must meet when the area below the waterline is subjected to a 2.5 m/s current and the one above it is subjected to winds of 25 m/s. However, their angles of incidence are not specified. In these regulations, the equipment number is the starting point to obtain the values for the lines. These values include number, minimum length for each and minimum breaking load (MBL). The guidelines establish the minimum requirements. [6]

A second classification society document IACS URA2 [5], "*Shipboard fittings and supporting hull structures associated with towing and mooring on conventional vessels",* standardises guidelines for designing and manufacturing the above deck components of mooring systems. It deals with "*…fittings and supporting structures used for the normal towing and mooring operations. Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the normal mooring of the vessel and the similar components used for the normal towing of the vessel".* However, "*other components such as capstans, winches, etc. are not covered by this Unified Requirement."*

Yet another document is from the Safety at Sea Committee of the IMO: *"Guidance on shipboard towing and mooring equipment"* [7]. *This circular is intended to provide standards for the design and construction of shipboard fittings and supporting hull structures associated with towing and mooring.* By *shipboard fittings, they mean bollards and bitts, fairleads, stand rollers and chocks used for the normal mooring of the ship and similar components used for the normal towing of the ship.* Therefore, components like winches have not been included. In this way, they are like anchoring systems [8], also left out of IMO guidelines.

On the other hand, ISO standards cover mooring and towing winches [9]. In terms of the guidelines followed by ship owners, classification societies define what a ship design must include for a vessel that belongs to a certain class. At the same time, there are sector specific regulations. For instance, chapter 7 of an OCIMF [3] document deals with mooring winches on crude tankers and Liquid Natural Gas (LNG) carriers.

This study will first compare existing regulations related to operation before looking at those on design and manufacture.

2.1 OPERATING REGULATIONS

These deal with the operating parameters for mooring winches involved in manoeuvres. The following aspects are considered:

- Load on the line or rope
- Rendering and recovering speed
- The drum's capacity to contain the line or rope
- Braking capacity

Table 2 provides an overview of the classification society standards. It is clear that a limited amount of data will be relevant to this study. Nothing is mentioned about the speed. There is little about loads and braking capacity;

Table 2 – Comparison of classification society standards

<table>
<tr><th></th><th>Det Norske Veritas</th><th>Lloyd´s Register of Shipping</th><th>Bureau Veritas</th><th>Germanischer Lloyd</th><th>American Bureau of Shipping</th></tr>
<tr><td>LOAD</td><td>Nominal load between 22% and 33 % of the mooring rope’s maximum breaking load (MBL)</td><td>Only specifies that the lower value is 15 tn-f</td><td>Not included</td><td>Only specifies that the lower value is 15 tn-f</td><td>Not included</td></tr>
<tr><td>SPEED</td><td colspan="5">Not included</td></tr>
<tr><td>BRAKING CAPACITY</td><td colspan="2">0.8 of the MBL of the mooring rope</td><td colspan="3">Not included</td></tr>
<tr><td>DRUM CAPACITY</td><td colspan="3">Determines minimum length for each rope</td><td>Determines minimum length for each line and storage value: containing 150 m. of rope with 80 mm. diameter.</td><td>Determines minimum length for each line.</td></tr>
</table>

only the Det Norske Veritas (DNV) sets an interval load value. The Lloyd’s Register of Shipping and DNV establish braking capacity. For the drum’s capacity, Germanischer Lloyd (GL) provides a minimum value based on a diameter and length to be contained.

In contrast ISO 3730 [1] includes the definitions mentioned above. It also has a table with the values relating to operating parameters for ropes whose diameters range between 18 and 48 mm.

2.2 DESIGN AND MANUFACTURING REGULATIONS.

Classification societies simply pay no attention to design and construction standards for mooring winches. For this analysis to be complete, data from ISO 3730 [1] and the OCIMF’s MEG 3 (3) should be considered. Table 3 gives a clear overview of the existing regulations.

Regulations must be standardised. In this way, equipment manufacturers can optimise their work by standardising designs and production methods. In turn, this would lead to economies of scale [8]. Classification societies focus on how the winches operate and forget about design and production. ISO standards and OCIMF documents deal with both operational and design factors. The two documents coincide; it is clear that the ISO guidelines have inspired the OCIMF regulations.

3. PROPOSAL FOR HARMONISING REGULATIONS

This proposal consists of adopting new criteria for which ISO 3730 – 2112 serves as a linchpin. In the few aspects they cover- load and braking forces- the classification societies coincide with ISO guidelines. However, the ISO deals with other working aspects, such as speeds and drum capacity. Moreover, these standards cover the design and manufacture of drums and warp ends, as well as speed control and display panels. The fact that classification societies do not mention these stands out (Table 3). Thus, the ISO standards are in a better position to inform a proposal to standardise regulations.

3.1 PROPOSAL TO HARMONISE REGULATION EXIGENCIES

An in-depth study of the contents of [1] [10] points the way towards these guidelines:

- The value adopted for the nominal load of the mooring winch should be 33% of the rope’s MBL [1] [3].
- The maximum load must not exceed 80% of the rope’s MBL [1].
- With constant tension winches, the following values are to be adopted to establish the rendering and recovery loads [1] :

    - Rendering loads - 0.5 times the rope's MBL.
    - Recovery loads - 0.5 times the equipment's nominal load.
- The equipment's dry running speed is to be 0.5 m/s (30 m/min.) [1].
- As for the drum's speed under nominal loads, this will vary according to the diameter of the line or rope. The following table provides the values to be adopted [1] (Table 4).
- As the creep speed, the recommended value is 0.5 times the nominal speed. Variations are in accordance with Table 5 [1] .
- Braking capacity is to be 0.8 times the rope's MBL [1].
- To avoid damaging the cable, the interior diameter of the drum is to be at least 16 times the line's diameter and six times that of the rope [1].
- For the drum design, the type of line to be used is 6 x 36 or 6x41 steel- cored Warrington Seale, in accordance with ISO 2408 [11]. A possible alternative, however, is to use mooring lines whose fibres comply with EN-ISO-1141 (2012) - Fibre ropes [12] [1].
- Drum capacity to hold the rope is to adopt a double configuration: minimum and maximum. These values are to follow the guidelines in Table 6 [1] .
- With the drum's exterior diameter, it should be possible to have between five and eight layers in the spool. This means that the exterior diameter is to have a value of (see Table 7)[1] .
- The drum has to be long enough to hold all of the rope indicated. In the case of split drums that have a stowage and working spool, the former is to have no more than five layers. The working zone is to have only one layer; its length cannot exceed 10 times the rope's diameter [1].
- If the drum is declutchable, its braking system must have a holding capacity equal to 0.8 times the rope's MBL [1].
- All the prime movers of the winches must have an automatic braking system equivalent to 1.5 times the nominal load for electric and y 1.25 for hydraulic systems [1].
- In the case of electric systems, the winch motor must be ready to carry out eight start-ups in an hour with intermediate two-minute periods of rest. For five minutes, it is to run at a power that exceeds 20 % of its nominal power [10].
- If the system is hydraulic, the motor's working pressure must be no more than 70 % of the maximum admissible continuous pressure. For five minutes, the system must be capable of running 15% above its nominal pressure [8].
- In electric systems, the motors are to have thermal class F insulation and class B heat resistance. The level of protection will be UNE 20324 – CEI 144, IP-560 when above deck and IP-540 in other cases [13] [14].

3.2 WORKING HYPOTHESIS

Using the exigencies of the regulations as a starting point, working hypotheses will be made:

- When the winch is in operation, its mechanical components must be capable of withstanding, as a minimum, a load that exceeds 25 % of the nominal load throughout the service life established by the manufacturer [10] .
- It is necessary to limit the difference in rope speed between the first and second working layer. When the motor is working at a constant speed, the ratio between the exterior (d_e) and interior diameters (d_i) of the drum, d_e /d_i, must fall between 1.5 and 3. When the motor has a variable speed, this may be between 2 and 5 [10].
- Ball bearings are calculated in accordance with ISO 281. There is a 90% confidence level for a 10-year service life, if the bearings are lubricated [8]. Grease chambers are used with easy access nipples, following the guidelines in ISO 7825 [15].
- Bearings are to be calculated with a 90 % confidence level and a service life of five years under nominal loading and speed conditions [16].
- The axles, clutch and gearbox are to be calculated at a 99% confidence level reaching the point of fatigue. The service life will be equivalent to the service life of the winch, under normal working loads [17].
- To ensure the long life of the cables and ropes, if the winch has warp ends, these must have a diameter that is at least six times that of the rope and 16 times that of the cable [3].

4. PROPOSAL FOR CALCULATING COMPONENT DESIGN

4.1. INPUT DATA

The data that are necessary for defining the winch are provided in reference [10]. These include:

- Type of work that the winch will carry out.
- Traction or pull.
- Rope length it needs to stow.

Occasionally, additional data are provided to complement the basic information. Among these data are: motor type desired to be the prime mover, line diameter to be used, rendering and recovery speeds, braking capacity, drum size and type and, finally, type of gear box.

The first step is to find out the nominal traction or pull. With this information, it is possible to obtain the value for the rope diameter and nominal speed, based on the guidelines from the ISO and MEG 3 [1] [3]. With these data, one can also define:

- Drum and warp ends dimensions
- Prime mover and reduction ratio

- Winch power
- Brake dimensions

4.2 DRUM DIMENSIONS

Ideally, the drum should fulfil the basic requirement of stowing all the line or rope provided for the winch. It should also meet the following conditions:

- The rope will not become damaged when it is coiled.
- The linear speed of the line being rendered and recovered will remain constant.
- In accordance with the drum size, the final dimensions of the mooring winch are reduced.

Because it is impossible to comply with the three conditions simultaneously, a priority list is needed. To minimize damage to the rope during the procedure, drums have to be built with large diameters. On the other hand a constant linear speed is the priority for the rope; the line must be completely reeled in one layer. This means that extremely wide drums must be produced and the final dimensions of the mooring winch will be affected.

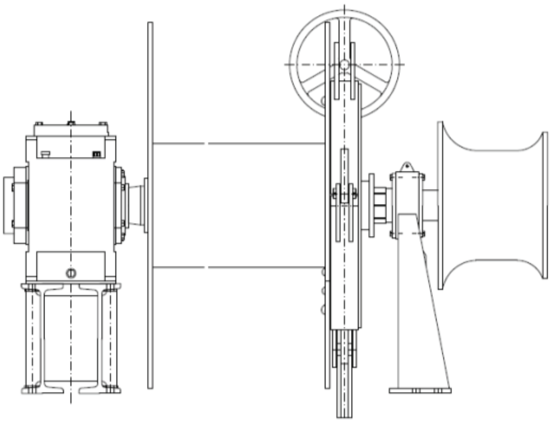

Figure 1 – Mooring winch with single drum, pull 80 KN. Source: Carral Design Engineering Solutions

ISO and MEG 3 guidelines distinguish between two types of drums: single and split. In the first type, the entire rope is reeled into a single zone, so that the load and linear speed vary from layer to layer. (See Figure 1). In the second type, the drum is split into a load or work zone and another zone for stowage by means of an intermediate element. In the load zone, the rope is reeled into one layer, so that a constant speed and load are maintained. (See Figure 2).

Guidelines for designing this mooring winch component can be found in ISO documents and MEG 3. There is great overlap between the two texts. Both sets of standards will be referred to for the design of the drum.
In practice, d_i is accepted as the interior diameter of the drum for the amount of rope it stows. [1] [3]:

$$d_i = 16 \cdot d_c \tag{1}$$

If it contains rope, the value that is considered will be six times the rope's diameter. With the exterior diameter d_e, one can obtain the capacity indicated in Table 6. This can be either minimal (2) or maximum (3):

$$d_e = 28 \cdot d_c \tag{2}$$

$$d_e = 33.1 \cdot d_c \tag{3}$$

If it contains cable, these coefficients will become 18 and 23.1 times the diameter.

There is an alternative to the ISO regulations. In this, the maximum diameter of the drum will be determined by the variation of speed that is admissible between the first and last layers. In [10] a suitable formulation helps calculate the value for the maximum diameter. A restriction of 25% is established as the variation in the nominal speed. By generalising this rule, the percentage value "r" is restricted as the admissible variation of the rope's linear speed. Thus one can obtain the expression that generally relates the parameters for the interior and exterior diameters of the drum:

$$d_e = d_i \cdot \left(1 + \frac{r}{100}\right) + 4 \cdot d_c \tag{4}$$

When the consecutive reeling in of the rope in the drum is analysed, it is assumed that the line in a number "n" of layers has been stowed correctly forming an equilateral triangle. It will therefore be possible to generalise the expression for the exterior diameter and of the number of layers "n" being reeled in (5):

$$d_e = d_i + 2 \cdot (n-1) \cdot d_c \cos 30 + 4 \cdot \mathrm{d}_c \tag{5}$$

$$n = \frac{(d_e - d_i - 4d_c)}{d_c \cdot \sqrt{3}} + 1 \tag{6}$$

Similarly, [10] offers the expression needed to obtain the third parameter: drum length. However, it is important to remember that the ISO mentions a clearance between the last layer and the exterior of the drum. This is to be at least 1.5 times the diameter of the line [1]. Expression (7) already takes this last observation into account.

$$l_c = \frac{1520\ \mathrm{d}_c^2 \cdot L}{[(d_e - 3d_c)^2 - d_i^2] \cdot k_e} \tag{7}$$

Thus, with conventional drums, the sizing process will already be complete. However, for split drums a further step of defining the diameter of work must be taken. This does not necessarily have to coincide with the minimum diameter of the stowage area. Once the length of the line L is known, the diameter of work d_t will be obtained considering stowage in a layer with a "m" number of turns:

$$d_t = \frac{L}{m.\pi} - d_c \tag{8}$$

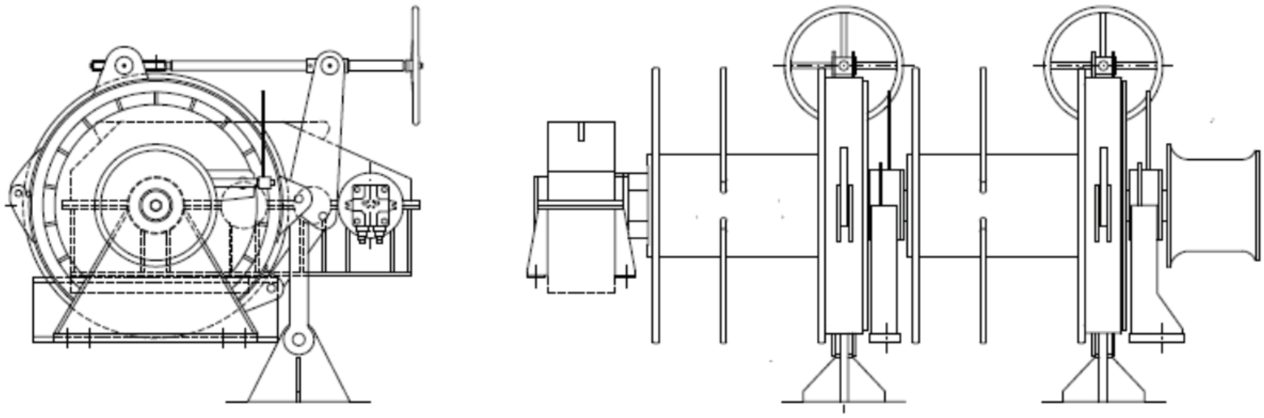

Figure 2 – Mooring winch with a split drum, pull 100 KN Source: Carral Design Engineering Solutions

For conventional spooling devices, the drum must be long enough to contain the entire rope within a number of layers that will range from five to eight. As indicated in [3] (pag. 140. 3 – MEG3) when dealing with elevated loads, it is convenient to limit the number of layers. If not, the line stowed in the lower layers may be bitten by the top ones due to the traction they exert. In these cases, the recommended stowage limit is four layers. With ropes subjected to a heightened load, a good option is to use drums of no more than five layers. In the work area, all the line is reeled into only one layer. This area is not to exceed 10 times the diameter of the High Modulus Polyethylene (HMPE) line or rope. If a mooring line is used, this amount can be reduced to six times its diameter. [1].

Table 8 summarises the drum geometry for constant tension mooring winches; it deals with the drum subject to load and the other one, a split drum.

A final step is to measure the maximum load that the line undergoes in its first layer when it is reeled in [11]. This is obtained by considering the nominal load (T) as that which is produced in the layer corresponding to the average drum diameter:

$$T_{max} = \frac{T \cdot (d_e + d_i)}{2 \cdot (d_i + d_c)} \qquad (9)$$

4.3 WARP END DIMENSIONS AND SHAPE

As is the case with the drums, the warp end diameters have to ensure that the mooring line will not be damaged when reeled in. The diameter of the rim groove will be the one obtained through the expression [2] [18].

$$D \geq 6 \cdot d_c \qquad (10)$$

In [18], to calculate the dimensions and profile of the warp ends, two models may be considered: one for the normal length and another for its longer counterpart (type C and E). The process merely involves calculating the value for the warp end's length end (L_{c}) and the value for the parameter M known as modulus:

$$Lc \geq 6 \cdot d_c \qquad (11)$$

$$M = \frac{d_c}{3} \qquad (12)$$

In Figure 3, the parameters for the warp end profile are shown; they coincide perfectly with what the regulation indicates [18].

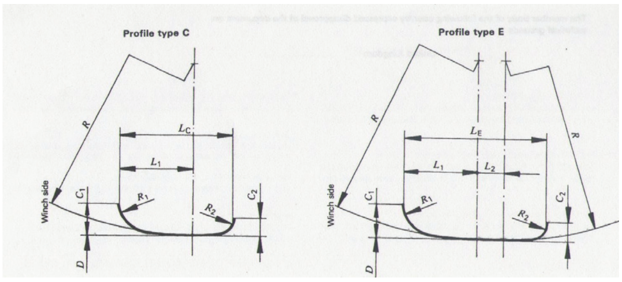

Figure 3 – Profile of the normal and longer warp end according to ISO 6482 (notation used in the mentioned standard), Source: ISO 6482

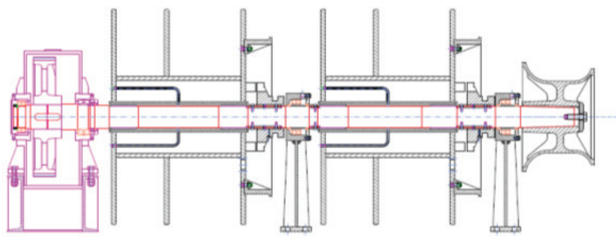

Figure 4 –Longitudinal section of the mooring winch with a double split drum, Source: Carral Design Engineering Solutions.

Table 3 – Comparison of the standards set by the classification societies, ISO 3730–2012 [1] and OCIMF/ MEG3 -2008 [3]

	Classification societies	*Norm ISO 3730–2012*	*OCIMF- MEG3*
DESIGN AND CONSTRUCTION			
Rope drum	Not mentioned	Defines: Capacity, interior and exterior diameter and length. In split drums, defines load zone.	Defines: Interior diameter and capacity. In split drums, defines load zone.
Warping end	Not mentioned	Optional, complying with ISO 6482	Not mentioned
Prime mover braking	Not mentioned	-Electric: 1.5· nominal load. -Hydraulic: 1.25 nominal load.	Not mentioned
Spooling device	Not mentioned	Optional	Not mentioned
Prime mover	Not mentioned	Electric in accord. with IEC 92 and IEC 529, hydraulic, in accord. with ISO 4413	Not mentioned
Emergency stop	Not mentioned	Within easy reach of equipment	Not mentioned
Protection	Not mentioned	Torque limiter needed	Not mentioned
Clutch	Not mentioned	Should be between prime mover and drum	Not mentioned
Control panel	Not mentioned	Manual, returning to neutral position	Not mentioned
OPERATION			
Drum load	Does not distinguish between them; only the DNV determines interval for nominal load according to the rope's MBL	0.33 rope's MBL	Between 0.22 and 0.33 times rope's MBL
Holding force		0.8 rope's MBL	0.5·rope
Recovery load		0.5 nominal load	Not mentioned
Rendering load		0.5 rope's MBL	Not mentioned
Nominal speed	Not mentioned	According to nominal load	According to nominal load
Light line speed		0.5 m/s.	0.75m/s
Creep speed		Inferior to 0.5·speed nominal and below 0.15 m/s.	Not mentioned
Drum brake capacity	GL and DNV determines 0.8 rope's MBL	Determine a value of 0.8 rope's MBL	Determines a value of 0.8 rope's MBL
Drum capacity	In general, not specific, except GL, which determines min. stowage capacity	Determine a min. and max. value for length in each diameter of rope	Determine a min. and max. value for length in each diameter of rope

Table 4 –Nominal speed for distinct line diameters

Nominal load (KN)	50	63	80	100	125	180	200	250	315	400
Rope diameter (mm)	18	20	22	24	26	32	36	40	44	48
Nominal speed (m/s)	0.25	0.25	0.25	0.25	0.2	0.2	0.16	0.16	0.13	0.13

Table 5 – Minimum speed for different rope diameters

Nominal load (KN)	50-63-80-100	125-180	200-250	315-400
Rope diameter (mm)	18- 20- 22- 24	26- 32	36-40	44-48
Creep speed (m/s)	0.125	0.1	0.08	0.065

Table 6 – Drum capacity

Nominal load(KN)	50- 63	80-100-125	180-200-250-315-400
Rope diameter (mm)	18 - 20	22- 24-26	32-36-40-44-48
Minimum capacity (m)	180	200	250
Maximum capacity (m)	360	400	500

Table 7 – Drum's exterior diameter

	Minimum capacity	Maximum capacity
Exterior diameter	28 times d_c	33.1 times d_c

4.4 TYPE OF PRIME MOVER GEAR RATIO

The two most frequent types of prime movers for mooring winches are electric and hydraulic motors (Figure 5 and 6). Hydraulic engines allow for a high degree of speed variation; constant torque can be maintained in each case. There are basically two kinds: the slow one with radial pistons and the fast one, which has axial pistons. The first are usually used in direct transmissions, whereas the others are generally attached to a reducing gear [8] .

Alternating current electric motors are cheaper. They are easy to use and demand less maintenance. However, they always require a reducing gear. For reduced power needs and when cost is a concern, the best option is an asynchronous, alternating current engines with a four-pole, squirrel-cage rotor. For bigger winches, motors with six or eight poles can be used. The choice of poles will depend on the total cost of the electric geared motor. When it is important to keep a constant speed, hydraulic transmissions with a variable displacement pump are needed. Occasionally a variable displacement pump engine or an electric motor with a frequency converter can be employed [8].

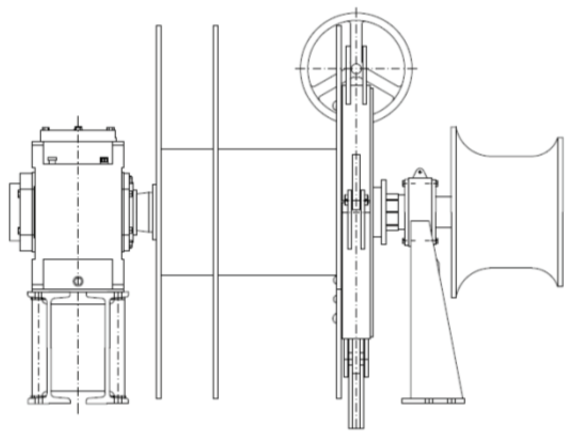

Figure 5 – Mooring winch with electric prime mover and reducing gear, pull 80 KN. Source: Carral Design Engineering Solutions

Table 8 – Drum dimensions

	Drum subject to load	*Split drum*	
		Stowage Zone	*Load Zone*
Interior diameter	$d_i = 16 \cdot d_c$	$d_i = 16 \cdot d_c$	$d_t = {}^{L}/_{(10 \cdot \pi - d_c)}$
Minimal external diameter according to ISO	$d_e = 28$ dc	$d_e = 28 \cdot d_c$	$d_e = 28 \cdot d_c$
Exterior diameter according to speed variation criterion r	$d_e = d_i \cdot \left(1 + {}^{r}/_{100}\right) + 4 \cdot d_c$	-	-
Length	$l_c = \dfrac{1520 \mathrm{d}_c^2 \cdot L}{[(d_e - 3 \cdot d_c)^2 - d_i^2] \cdot k_e}$		$l_c = 10 \cdot d_c$ for lines $l_c = 6 \cdot d_c$ for ropes

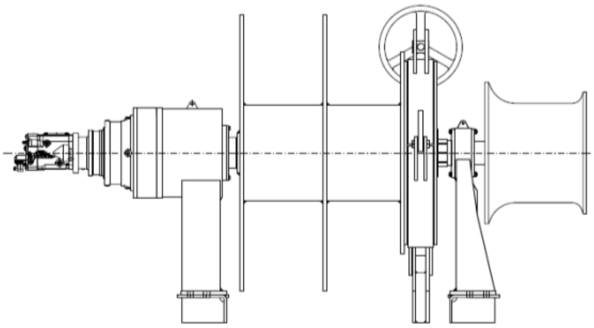

Figure 6 – Hydraulically-operated mooring winch, pull 60 KN. Source: Carral Design Engineering Solutions

The transmission ratio is defined as the ratio between motor and drum speed. It can be obtained through the following expression [19]:

$$i = \frac{0.00942 \cdot \left(d_e + d_i\right) \cdot N_m}{V_s} \tag{13}$$

4.5 POWER NEEDED FOR THE MOORING WINCH

This will be the average power that the prime mover must provide to the mooring winch. It depends on the average lifting speed, on the load correlative to this lifting speed and the type of prime mover used. It is necessary to determine if the prime mover is direct or through a reducing gear, as well as to find out the efficiency. This formula will be used:

$$P\,(W) = \frac{T \cdot V_s}{\eta_t} \tag{14}$$

If the lifting speed is not specified by the client, the values within Table 4 can be used. There is insufficient experimental data. Therefore, as a preliminary approximation, the stream performance can be taken as the product of the gear box´s stream efficiency times the drum efficiency [10] [19]. The efficiency of the gearbox depends on the number and type of wheels within each reduction stage. Obviously, if the activation is direct then the performance will be a unit. The most common performance values can be found in [8].

4.6 DETERMINING THE BRAKE

Every mooring winch must contain a brake that will allow it to slow down or come to a halt when it is activated.. (Figure 7)

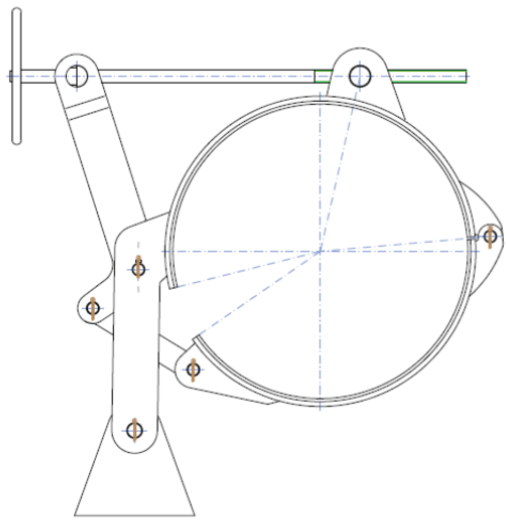

Figure 7 Fixed band brake. Source: Carral Design Engineering Solutions

The calculation for the band brake involves considering the reference [8]. Moreover, one must remember that the holding force in drum F_r is now about 80% of the line or rope’s breaking load, as recorded in Table 3.

$$F_r = 0.8 \cdot MBL \tag{15}$$

5. CONCLUSIONS

The IMO and the classification societies look at how the accessories of the mooring system (bitts, fairleads and bollards) are designed. However, in all things concerning the winch, these entities only regulate aspects pertaining to its operation, such as load and braking capacity. They ignore speed or stowage capacity. Design and manufacture are also completely overlooked. On the other hand, the ISO regulations and the OCIMF publication consider functional and design aspects. Both sets of these standards largely coincide; the former influenced the latter.

The contents of ISO 3730 – 2112 have been compared with different implementation regulations. It includes proposals that coincide with the operational aspects that are covered by the classification societies, such as load and braking power. The ISO guidelines go much deeper. They alone cover other areas of operation, such as speed, drum capacity, drum design and construction, warping ends, speed control and control devices. For this reason, the ISO norms have been used as the starting point for harmonising regulations.

The essential information for defining a mooring winch is determined by the function it must accomplish, as well as by its load and the amount of rope it must stow. It is also convenient to include other data, such as the type of engine chosen as its prime mover, the diameter of the line used, its drum dimensions and the type of gear box used.

The procedure proposed here first entails knowing the nominal load to obtain the value for the line's diameter, based on the regulations contained in the ISO and MEG 3. The proposed calculation method continues to use the line's diameter to define: the drum and warping end dimensions, prime mover type, stream ratio, mooring winch power and brake type. With all these data, the mooring winch is fully defined.

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7. APPENDIX 1

Definitions (3828:1984 Shipbuilding and marine structures – deck machinery vocabulary)

DRUM LOAD – (KN) – (CORRESPONDS WITH HALF DRUM LOADS),The maximum rope tension measured at the drum exit when the winch is hoisting or hauling in at the nominal speed with the rope being wound on the drum in an average layer.

HOLDING LOAD – *(KN*) – The maximum tension that can be maintained by a breaking/locking system in the first layer.

STALLING LOAD – (KN) – The maximum rope Tension measured at the drum exit when the drum ceases to rotate in the direction of haul, the prime mover being set for maximum torque and the rope being wound on the drum in a single layer.

RECOVERY LOAD – The maximum rope tension measured at the drum exit when the drum ceases to rotate in the direction of haul, the prime mover being set for maximum torque under automatic control and the rope being wound on the drum in a single layer

RENDERING LOAD – The maximum rope tension measured at the drum exit when the drum ceases to rotate in the opposite direction to the applied driving torque, the prime mover being set for maximum torque under automatic control, with and the rope wound on the drum in a single layer

NOMINAL MOORING SPEED –The maximum speed that can be maintained by the winch when it is applying the drum load.

LIGHT LINE SPEED – The maximum rope speed that the winch can maintain with the rope wound on the drum in a single layer, and with negligible tension on the rope, normally not more thann 10% of tha drum load.

CREEP SPEED –The minimum uniform speed measured on the first layer that the winch can maintain under drum load.

MBL MINIMUN BREAKING LOAD- line's breaking load