DESIGN CONSIDERATIONS FOR TRAWL WINCHES

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For efficient functioning of a trawl winch it is essential that all component parts should be designed carefully taking into consideration all the relevant factors such as quantum and type of load each component is subjected to, amount of maintenance it will receive during actutal operation, type of drive for the winch etc.

Based on the practices adopted at the Central Institute Of Fisheries Technology certain guide lines are proposed in this paper for designing of trawl winches.

INTRODUCTION

The trawl winch can, quite justifiably be described as "the arms" of a trawler in view of the vital role it plays in handling the trawl gear. The modern trawl winch is an offshoot of steam cargo winch and there have been little change in the basic concept of the trawl winch over the years except, perhaps, the introduction of electricity and hydraulic power for driving and controlling them.

Failure to take into consideration all the relevant factors in designing a winch quite often resulted in an unsuitable or inefficient trawl winch seriously jeopardising the proper working of the boat.

In the following pages certain guide lines are proposed for designing trawl winches to achieve maximum efficiency consistant with economy.

Load capacity of the trawl winch.

The size of the boat and size of the net used, determine the load capacity of the winch. *The working load* of each drum of the trawl winch is the pull on the warp while the fishing gear is hauled up with the boat moving ahead at trawling speed. This value is considerably higher than the static pull measured on the warps while the fishing gear is towed. Hence suitable allowance must be made when calculating the working load of the winch based on static warp tension measurements.

The power required to haul up the trawl gear is the product of the total tension and hauling speed which can be expressed by the simple relation

$$P_w \text{ (metric HP)} = \frac{T \times S}{75} = \frac{2 \pi N W R}{4500}$$

Where Pw is the power required at any particular instant.

T = Total load on all the warps (kg.)
S = Hauling speed (m/sec)
N = Rpm of winch drum.
R = Radius at which the warp is being wound at any instant (metres.)

Koyama (1966) worked out a relationship between power required for trawl winch and power of main engine for boats with 1200 - 3500 HP engines.

$$P_w = 80 + 0.0058\,P$$

P_w = power required by winch

P = Maximum continuous shaft horse power of engine.

Figure I gives this relationship in the in the case of smaller boats.

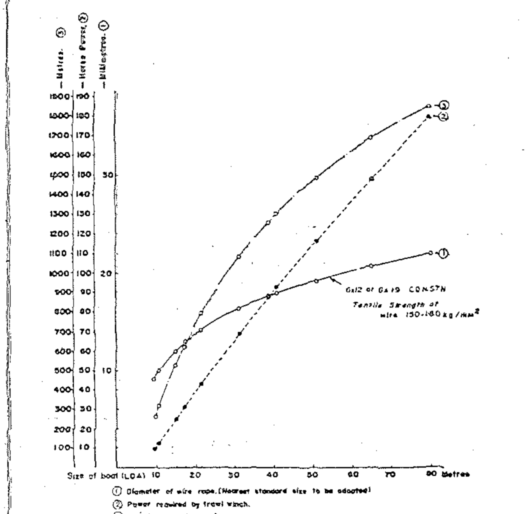

FIG. I. RELATION BETWEEN LENGTH OF BOAT AND (1) DIAMETER OF TRAWL WARP (2) POWER REQUIRED BY TRAWL WINCH AND (3) LENGTH OF WARP

Nominal size of trawl winch:

The nominal size of trawl winch corresponds to the nominal load expressed in tonnes, which the winch is rated to lift.

Nominal load:

Nominal load of a trawl winch can be defined as the sum of the maximum working loads in all the warp drums which work at a time, measured at the end of each warp, when the winch is pulling the load at nominal speed, through a single sheave for each warp.

Nominal speed:

This is the maximum speed atwhich the winch is rated to lift the nominal load. For fishing boats this can be taken as 1 m / sec. which approximates to the average recomended hauling speed for trawl winches.

Size of warp and major dimensions of warp drums.

Size of warp:

The size of the trawl warps depend on working load. A factor of safety of 6 is considered essential in view of the severe operating conditions and inadequate maintenance of these warps. The size of the warp should be selected such that

$$R_B \geqq 6T$$

R_B = Breaking load of warp

T = Maximum anticipated load on each warp.

Fig. 1 gives the relationship between the size of boat** and size of trawl warp.

Dimensions of warp drum:

The main dimensions of the warp drums viz. the inner diameter (D_1) outside dia. (D_2) and length l depend upon the size and total length of warp each drum is required to hold, which in turn is

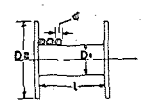

Fig. 2. WARP DRUM.

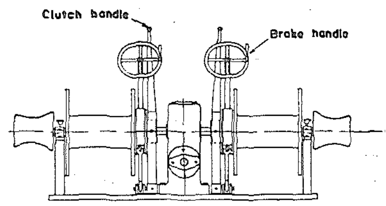

Fig. 3 a. DRUMS ARRANGED IN THE SAME SHAFT.

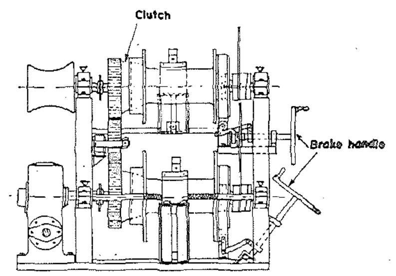

Fig. 3b. DRUMS ARRANGED SIDE BY SIDE ON PARALLEL SHAFTS.

** Size of boat (LOA) is taken as the basis as other parameters such as power of main engine, warp tension etc. are generally functions of LOA of boat.

dependant on the depth of operation and type of fishery. It is customery to provide sufficient length of warp to operate in the deepest possible waters consistant with the size and range of the boat.

Miyamoto, (1959) recommended the length of warp to be released for bottom trawling as follows

$$L = 3D + 7.5$$

L = Length of warp to be released in metres.

D = Depth of water in metres.

An allowance of 20% is added, and this gives the total length of warp in each drum. The relation governing the main dimensions of the warp drum and total length of warp it can hold is given by the expression (Torbon, 1967)

$$Lw = \frac{K \pi l (D_1^2 - D_2^2)}{4 d^2}$$

where Lw is the length of warp in each drum and K = coefficient of stowing which is 0.75 for winches without warp-guiding gear and 0.85 for winches with warp guides. D1, D2, l & d represent the same values as in Fig. 2.

Futher $\frac{D_2}{D_1} \simeq$ 3-6 for small winches
5-10 for large winches

$\frac{D_2}{l} \simeq$ 0.7-1.2 for small winches
1-1.5 for large winches

Also $D_1 \geqq$ 10d or 125 mm whichever is higher (HSN, 1971).

(for small and medium size winches)

It is essential to increase the outer diameter D_2 so obtained by 4-5 times the diameter of the warp to avoid spilling of the warp over the flange of the drum.

As a general guidance the length of warp required for different size groups of boats (bottom trawlers) is given in Fig 1. If the length of warp used is too long such as in the case of deep sea trawlers the diameter of warp should be increased in steps towards winch end to prevent breakage of the warp due to its own weight. Where a separate drum is used for the operation of a trynet the sizes of the same will also have to be worked out in according with the procedure outlined above.

The warp drum freely floats, being coupled to the shaft by means of clutches. It should be capable of (1) freely rotating on the shaft, (2) being coupled to the main shaft of winch through clutches and (3) being locked stationery while trawling.

Warp drums can either be built up with M. S. plates or cast. Cast drums are however heavier than built up ones and are liable to be broken and repairing also presents problems.

As a rule, warp drums for a small trawl winches are cast and those for large winches are fabricated.

Arrangement of warp drums:

Trawl winch in its simplest form is provided with only 2 drums, one for each warp and occassionally with third one for operating a trynet. But in combination winches there are three, four or even six drums to suit the particular type of operation.

Warp drums can be arranged either side by side on the same shaft or on two paraller shafts as shown in Fig. 3a & 3b

Winches with drums fixed on the same shaft (Fig. 3a) require less longitudinal deck space for installation but these types of winches are not rigid enough due to the long shaft and require solid support at the base and deck. Winding of the warp onthe drums evenly will also present difficulties if intermediate floating pulleys or the gallows happen to be too near the winch as the warp will become very stiff and will not lend itself to evenly winding on the drum. On the other hand winches with drums fixed side by side (Fig. 3b) on parallel shafts are compact and leading the warp to the gallows present less problems. This arrangement is particularly suitable for 'double rig' trawling. Working of the latter is however noisy due to the use of spur gears.

The arrangement of drums should be chosen taking into consideration factors such as space available, type of drive, type of fishing, position of gallows and guide pulleys, difficulties likely to be encountered in leading the warp to the gallows or guide pulleys and winding it on the drum.

Hauling speed:

The speed of rotation of the winch remaining constant, the hauling speed varies continuously, being minimum initially and maximum when the drum gets full.

Excessive hauling speed will cause breakage of the net and warp besides putting considerable strain on the engine and the too slow a speed will result in loss of time and allow escape of the live fishes, particularly the fast swimmers. The best average hauling speed for smaller boats below 20 m length is 0.8 to 1.0 m / sec and for larger boats 1.5 to 2 m / sec. For midwater trawls the hauling speed should at least be equal to the trawling speed.

Hauling speed at any instant is given by the expression.

$$S = \pi D n$$

S = hauling speed in m / sec.

D = Dia. of the point where the warp is being wound at that instant (in metres.)

n = Rev. / sec of warp drum.

Average or mean hauling speed of a trawl winch is given by substituting D in the above expression by

$\frac{D_1 + D_2}{2}$, D_1 and D_2 being inner and outer diam. of warp drum.

If geared or belt drive is used it must be ensured that the sizes of pulleys ,gear wheels etc. are so adjusted as to get the desired hauling speed. In case of counter shaft drives the speed of counter shafts should be limited to about 1000 RPM to avoid excessive vibration and difficulties regarding maintenance of bearings etc.

Main shaft:

The winch main shaft is subjected to combined bending and torsion and its size should be calculated accordingly.

Gear drives:

Both worm and spur gear drives are used in mechanical and electrical trawl winches. Worm-gear drive is advantageous where high reduction of speed is required and where drive to the winch is taken off the main engine through counter shafts or the winch is directly coupled the main engine through pulley or chain drives. This is particularly so in the case of winches with drums on a sigle shaft. Further the worm gear provides a self locking arrangement provided,

$$f > \tan \alpha$$

where f = coefficient of friction of the worm-wheel.

α = lead angle of worm

For M. S—gunmetal or phosphor bronze worm-wheel combination working in an oil bath α should be below 12° - 14° to obtain self locking qualities.

Heat dessipation does not present any major problem as the duration of continous operation of the trawl winch is quite small and there are long intervals between operations.

Direction of rotation of the winch:

Due to the differences in arrangement of drums it is difficult to precisely define direction of rotation of winches. In order to reduce stress on the base and foundations it is advisable to wind the warp through the lower side of the drum. This will not however, always be possible as a high hatch coaming or some such structure can foul the warp. In such cases the winches have to wind through the upper side of the drum.

The direction of rotaion of the winch should be determined taking into consideration the direction of rotation of the driving machinery, gearing, obstructions in way of the warp etc.

Bearings:

Various bearings for the winch should carefully be selected with an eye on

(a) Service conditions and mode of loading

(b) Maintenance and repairs

(c) Lubrication.

In view of the slow speed of the main shaft of the winch ordinary shell bearings with provision for grease lubrication will be quite sufficient. Gun metal has been found to be the most suitable material for making shell bearings for trawl winches.

Clutches:

Operationa canditions require that each warp drum be provided with separate clutch so that it can be engaged or disengaged easily and quickly. The types of clutches generally used in trawl winches are;

Jaw clutch:

This is the simplest and most commonly used type of clutch. This is quite inexpensive, easy to maintain and is positive in action. If square jaws are used, engaging RPM should be limited to 10-14. If spiral type jaw clutch is used engaging speed can go up to 100 RPM.

The main defect of jaw clutch is that it is difficult to disengage under load. It is however possible to obtain easy disengagement under load if the faces are case-hardened and machined and kept properly lubricated. Providing a light taper not exceeding 2° on the active faces also helps disengagement.

It is customary to cast one half of the jaw clutch integral with the warp drum. It has been found that it is advisable to cast the jaw clutches separately and fit one half to the drum by means of Allen screws. This renders heat treatment and machining of faces of the jaw clutch as well as repairs in case of breakage, easy.

Cone clutches:

Cone friction clutches are also quite frequently used in trawl winches. Here the warp drum of which the 'Outer cone' of the clutch forms a part is moved to engage or disengage, while the inner cone remains stationery on the shaft. This fecilitates smooth engagement and disengagement unlike the jaw clutch.

For easy disengagement (fig. 4)

$$\operatorname{Tan} \frac{\theta}{2} \geq f$$

Where f is the cofficient of friction.

Cone clutches, however, have the inherent tendency to slip out of engagement automatically unless sufficient axial force is applied continously and provision must be made for this while designing the winch.

Force Fa required to produce normal force Fn is

$$Fa = Fn \operatorname{Sin} \frac{\theta}{2} \text{ (Vallance et. al. 1951)}$$

As the drum is engaged while the cone

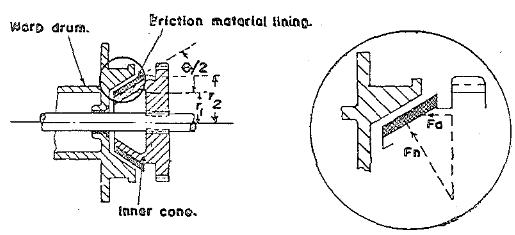

Fig.4. FRICTION CONE CLUTCH.

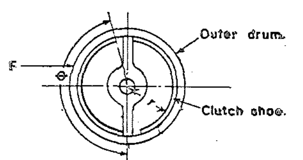

Fig.5. EXPANSION CLUTCH.

clutch is in rotation.

$$Fa = Fn \left(\sin \frac{\theta}{2} + f\cos \frac{\theta}{2}\right)$$

The value of $\frac{\theta}{2}$ if fibre lining is used will be 12–15°

It will be advisable to provide some quick actuating locking arrangement for the handle to avoid the necessity of keeping a pressure on the handle all the time.

Clutches should be disigned to haul up the nominal load at nominal speed and they should not slip up to 150% of its rated capacity.

Let L_N be the load at a drum radius r_d (Fig 4) then for each drum of a 2 drum winch,

$$\text{Torque} = L_N \; r_d$$

If the clutch is to slip at 1.5 times rated load, maximum torque for the clutch

$$= 3/2 \, L_N \; r_d$$

$$T = \int dT$$

$$3/2 \, L_N \, r_d = 2/3 \, \pi \, f_p \, (r_2^3 - r_1^3)$$

p, the nominal pressure should be limited to the value recommended by the manufacturers of friction material, and r_1 and r_2 should be selected as large as practicable.

Expansion clutch :

Expansion clutches of different description are used consisting, principally of expanding shoes fixed to the shaft and an outer drum cast integral with the warp drum

Expansion clutches are quite efficient in operation but are more expensive than jaw or cone friction clutches.

In expansion clutch (Fig. 5),

$$T = 2fpwr^2 \, \theta \qquad (\theta \text{ in radians})$$

w is the width of the shoe.

Electro magnetic clutches:

Electromagnetic or hydraulically operated clutches are not recommended in the present juncture in view of the delicate nature of these clutches and difficulties likely to be encountered in their maintence.

Warp heads:

Warp heads are used for operating derrick and for similar hauling purposes. At least two warp heads should be provided in each winch. The smallest dia. of the warp head should not be less than 12-15d where d is the dia. of the warp. The minimum length l_h (Fig 6) should be decided according to the relation.

$$l_h = 5d + (150 - 200 \text{ mm.})$$

The profile of the warp head should be such as to provide sufficient friction surface and to allow the warp to always slip towards the centre, when the warp is wound round it and heaved.

Warp heads should not contain any projections or whelps but should have a plain surface. Close grained cast iron is ideally suited for warp heads.

Warp guiding gear:

It is necessary to provide warp guiding gear for uniformly winding the warp on the drum lest the warp should wind unevenly, only at one point, swelling that particular portion, while

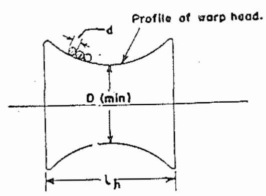

Fig. 6. WARP HEAD.

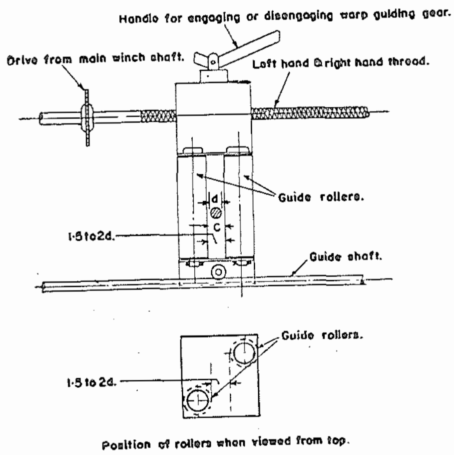

Fig. 7. WARP GUIDING GEAR.

leaving cavities on the other portions of the drum. This will result in crossing of warps and shock loads. Further the quantity of warp that can be accomodated in the drum is increased when the warp guiding gear is used. Different types of warp guiding gear - either mannually or mechanically operated - are used but all of them basically consist of a carriage with guide rollers which is moved along the length of the drum by means of a screw.

For winding the warp evenly on the drum without any gap between successive coils,

$$N' = \frac{N \times d}{Ps}$$

N' = Rpm of lead screw.

N = Rpm of drum

d = dia. of warp

Ps = Pitch of screw,

The rollers should be fixed diagonally (Fig. 7) so that the actual clearance between them is only a little over the diameter of the warp, as otherwise there will be considerable waste motion of the grinding gear when it reaches on end of its travel and returns.

$$C = 1.5 - 2.0d$$

Warp guides should be capable of being disengaged and moving freely while the warp is paid out and be provided with controls for engaging and disengaging as and when required. It should also be possible to take the warp out of the guide block quickly.

Brakes:

The functions of a brake in a trawl winch are to assist control of warp while paying out and hold the drums locked while towing. Brake wear occurs mostly during the earlier operation whereas the full capacity of the brake is utilized only during the latter operation.

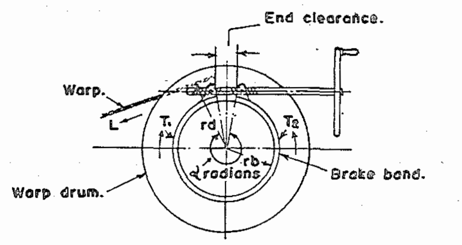

Fig. 8. LOAD ON THE BRAKE BAND.

The type of brakes used in most trawl winches are the hand operated band brake, lined with friction material. In order to hold a load L at a radius r_b of the drum (Fig. 8).

$$(T_1 - T_2)\, r_b \geq L r_d$$

T_2 and T_1 are tensions on the slack and tight sides of the brake band

Also $\frac{T_1}{T_2} = e^{f\propto} = 10^{0.0076 f\propto}$ (Russal et. el. 1958) where f = coefficient of friction and $\propto$ = angle of contact of brake band in radians.

The size of the brake band should be calculated considering maximum load during trawling. Beyond a predetermined load, usually 50% above maximum calculated load the brake should slip in order to avoid breakage of the warp, loss of gear or damage to other parts of the winch, should the gear get entangled with any under water obstructions. The possibility of lubricants such as oil or grease entering the face between the brake drum and brake strap resulting in reduced coefficient of friction should also be borne in mind in this context.

The diameter of the brake drum should be made as large as possible in order to reduce stress on the brake band and brake wear. Heat transmission has not been found to present any difficulty due to the intermittant nature of the working of the brake, and the comparatively light load under which slipping occurs while releasing of the warp.

If screw arragement is used for tightening the brake band it should be possible to completely apply or release the brake in 2-$2\frac{1}{2}$ turns of the handle. Left handed and right handed threads of coarse pitch should be provided on the brake spindle in order to achieve quick application and release of the brake.

Controls:

The controls of the various functions of the trawl winch can be efficiently and effectively handled by as few persons by grouping the control together whereever possible.

The basic duties of a trawl winch are,

(a) *Paying out:* During this operation the drums are loose on the shaft, as the trawl immersed in water is run out by the forward movment of the boat. No power is required from the winch. The warps are kept tight by the brakes which also help to keep the length of warp paid out equal. The warp guiding gear should slide freely along its guide, being disengaged from the drive.

(b) *Trawling:* During this operation the drums are decultched and brakes are locked. The drums remain stationery.

(c) *Hauling:* Power from winch is utilized only during this part of the cycle. The brakes are released and the drums engaged by their respective clutches.

The control livers, wheels etc. should easily be accessible. Long levers should be counterbalanced with suitable weights. No manually operated control should require a force exceeding 15-20 Kgf at the hand lever or wheel for operating them.

All the controls, levers, wheels etc. should be liberally dimensioned to avoid failure at critical moments.

Type of drive:

Modern trawl winches are driven by one of the following means.

(a) Mechanical, (b) Electrical and (c) hydraulic. Each system has its own merits and disadvantages, (Velu, 1964)

Merits

Mechanical	Electrical	Hydraulic
1. Simple	1. Compact & - requires less space.	1. Compact and rugged.
2. Reliable	2. Installation does not present much problems as the cables can be laid along any convenient position of the boat.	2. High starting torque 3. Continuous stepless speed control.
3. Easy to maintain & repair.	3. Better response and easy to control.	4. Quick acceleration.

4. Comparatively expensive.	4. Flexible in operation.	5. Easy and flexible in operation.
		6. Requires little maintenance.
		7. Automatic adjustment of torque to load.
		8. Easy to control.
		9. Less of installation problems as the pipes can be laid convenient along the side of the boat.

Disadvantages:

1. Bulkey and requires more space.	1. Highly susceptible to be damaged by corrosion.	1. Maintenance & Repairs requires special skill.
2. Presents installation problems as the countershafts etc. have to follow definite straight lines which quiet often present practical difficulties.	2. Requires special skill for operation and maintenance which is not normally available in a small ship.	2. The system should be kept very clean as even small particles of dirt can damage the working of the winch.
3. Where the winch is driven by the main engine itself the hoisting speed depends upon the Rpm of engine. This dependance between speed of ship and drive of trawl winch is very inconvenient.	3. Requires a separate generator of large capacity for power supply.	3. The comparatively high pressure of working fluid requires leak proof jointing etc.
4. Not flexible in operation.	4. Less reliable.	4. Very expensive.
5. Controlling and regulating difficult.		
6. Mechanically less efficient due to losses in gearing shafting and dearing.		

In the conditions obtaining in this country the mechanical type of winches is quiet suitable for boats below 15 m. length and hydraulic winch is recommended for boats above this size.

In view of their susceptibility for corrosion damages, electrical winches cannot be recommended in tropical countries like ours, for use in fishing boats.

General:

The trawl winch is exposed to sun and rain, receives practically no maintenance but has to be in good working condition at all times. This demands that the various meterials and components used in the construction of the winch should be of top quality. In view of the severe corrosion all parts exposed should be generously dimensioned without however sacrificing lightness. Same size, bolts, nuts and other fittings should be used whereever feasible with a view to variety reduction and to fecilitate interchangeability.

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