Chapter 11

DOUBLE DRUM TRACTION WINCH SYSTEMS FOR OCEANOGRAPHIC RESEARCH

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The traction winch, as defined in marine deep water applications, is the primary component of a system designed to provide a significant tractive or load-bearing effort to subsea cable or umbilical. Conventional traction winch systems utilize two sheaves with multiple cable grooves to apply this tractive effort via elliptically reeving cable around the two sheaves. Although traction winches have been around for many years, earlier systems were designed for use with wire ropes in applications where high line pulls tended to knife or bury the outer layer of wire rope into previous layers of rope on the drum. The concept of using a traction winch to extend the life of the cable other than by preventing knifing was usually not considered and in fact some earlier traction winch systems earned the reputation of "cable eaters".

Advancements in instrument packages and vehicles to perform more complex, intervention tasks at greater depths have placed greater demands on the cables and umbilicals linking them to the surface. Cable tensions in these applications will frequently approach 50% of the cable breaking strength and, as a result, larger minimum bend diameters must be maintained throughout the system while handling greater loads to obtain the best performance and extend the life of the cable. The need for optimizing cable and umbilical performance and the introduction of new cable designs to meet these demands have resulted in an ever increasing challenge for handling systems which allow optimum cable performance and maximize cable life.

1.0 TRACTION WINCH SYSTEM ADVANTAGES

Sheave diameter is determined by the cable's minimum bend diameter which increases as resulting loads approach 100% of the cable breaking strength. Large diameter traction winch sheaves permit cable to be reeved in a single layer and to further avoid being subjected to unacceptable bend diameters. Traction winch system sheaves absorb high line pull loads by allowing the cable to work in a formed groove at the required minimum bend diameter. This single-layer effect is significant when compared with high line pull conditions in a conventional drum winch in which cable works on itself as a result of multiple layer wraps.

In this case, the cable will, at cross-over points, be subjected to a bend diameter equal to that of the actual cable diameter, resulting in possible damage to the cable. In addition, under extremely high tension, the cable may also pull down with a force great enough to penetrate existing cable layers on the winch drum.

The effects of multiple grooving, single cable layering and applied torque from powered traction sheaves are combined to absorb high line tension, translating to low tension as cable exits the inboard traction sheave. The cable is then stored in multiple layers on a storage winch under low line tension in a range equal to approximately 10 to 15% of maximum operating load throughout the entire cable scope. Consistent, low storage tensions also improve accuracy and repeatability when levelwinding the cable. As a comparison, storage tension on a conventional drum winch can vary between cable layers in response to varying dynamic tow loads.

2.0 THEORY OF OPERATION

Traction winches are a friction drive device. By maintaining a sufficient arc of contact, an adequate coefficient of friction, and appropriate back tension on the inboard end of the cable or rope, controlled movement of the cable will be affected by powering the traction sheaves.

We can use the formula: $T_1=T_2e^{\mu\beta}$ to calculate the total developed line pull.

B = included angle formed by arc of cable contact with sheave (radians)

μ = coefficient of friction

e = 2.718

T_1 = high tension leg

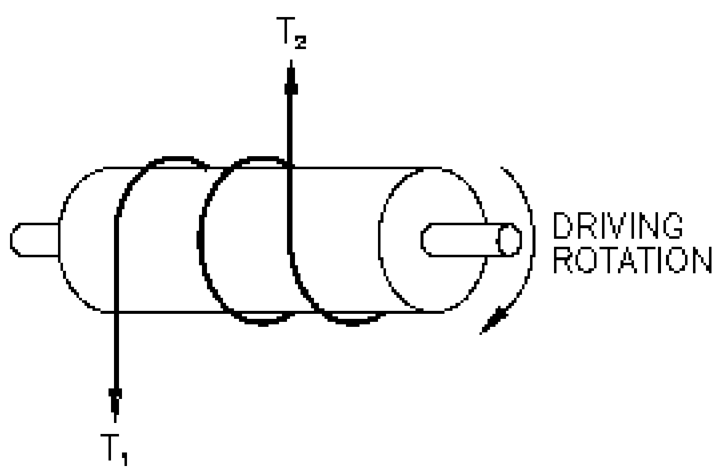
T_2 = low tension leg

Note that if T_2 , the low tension leg is brought to zero then T_1 also goes to zero.

Another important point regarding traction winch design is in addition to the coefficient of friction, traction depends on the arc of contact and not the diameter of the sheave. If the arc of contact is two half wraps or 360 degrees, traction would be the same with a 50 inch diameter sheave as with a 100 inch diameter sheave. It makes no difference that the length of rope in contact is twice as long with the larger sheave.

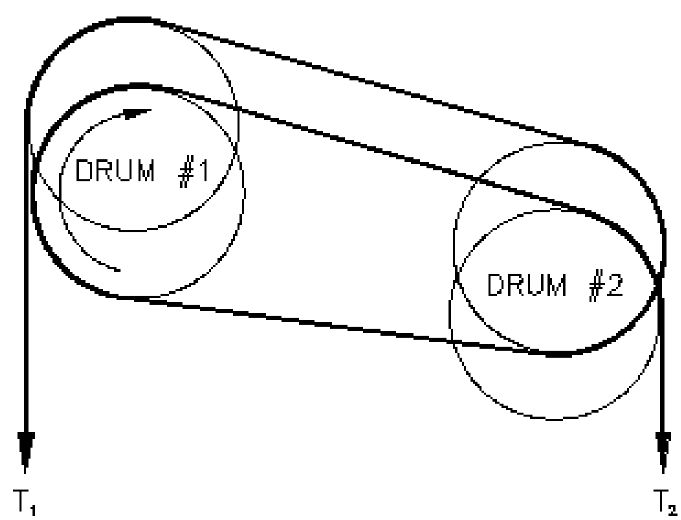
Figure 1 shows the most common form of traction device is the single drum capstan used extensively on ships for handling mooring lines. The drawback to handling long lines is the axial movement of the line across the face of the drum. This causes frictional wear and/or rotation of the line. These are best used when low line to drum friction coefficients are encountered and the line can slide axially across the drum face.

Figure 1



The double drum traction winch with a companion storage winch is commonly used with long lengths of cable. In most cases, both drums are powered and have multiple grooves. The cable is reeved from drum to drum and groove to groove providing the axial movement without producing the axial friction inherent in a single drum capstan.

Figure 2



Earlier double drum traction winches were designed to generate high line pull when using a conventional winch was not feasible. They did not always treat the cable very well. Many systems were designed using a single drive powering both of the sheaves. The sheaves were simple offset one half of the cable diameter to help with the transition of the cable from groove to groove. This created several forms of abuse to the cable. Both of the sheaves are forced to turn at the same speed however due to machining tolerances and groove wear, different surface velocities on the two sheaves occur. This requires that the cable slip on one of the sheaves. If the friction is high enough, the cable may not be able to slip and extremely high tension can occur within the wraps and armor wires can be broken.

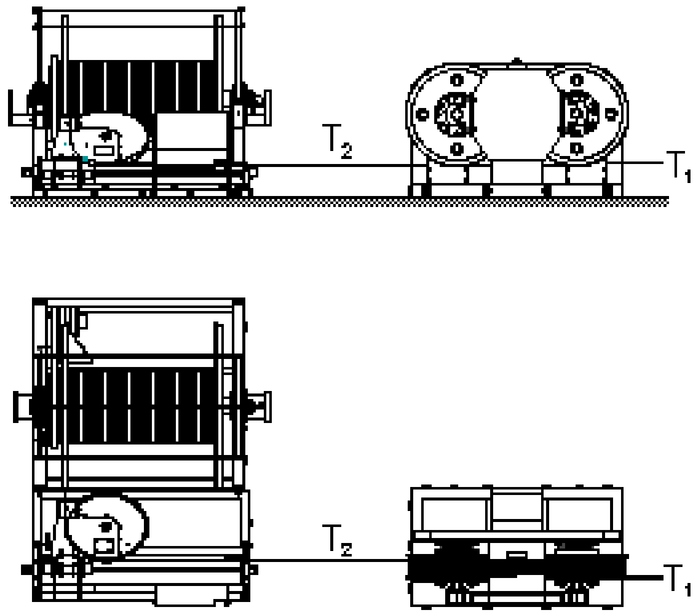
The problem with simply offsetting the sheaves by one half a cable diameter is that while it may appear that a smooth transition is taking place in fact the cable is subjected to a sharp bend as is leaves the sheave and a rolling or twisting of the cable also occurs.

Another form of abuse can occur between the traction winch and storage winch. Using a storage winch and conventional guide roller levelwind sometimes subjected the cable to severe bending due to the close proximity of the storage winch and traction winch.

3.0 ADVANCES IN TRACTION WINCH SYSTEM DESIGNS / OPTIMUM USE AND CONSERVATION OF DECK SPACE

The modern traction winch system is a multi-component system designed to extend cable life while optimizing available deck space. Current traction winch system designs includes a dual sheave traction winch, storage winch, right-angle levelwind and hydraulic power unit.

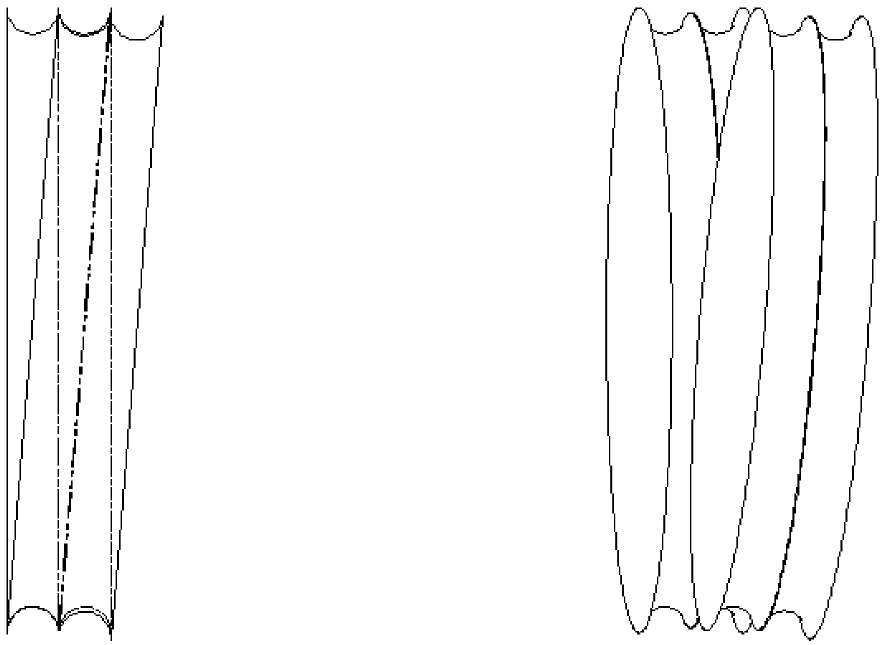
Figure 3



Advances in traction winch systems include designs featuring cantilevered traction winch sheaves with exceptionally high line pull ratings. The cantilevered sheaves allow clear passage of cable on the top and bottom of the traction sheaves. This arrangement allows cable to simply be lifted off the traction winch sheaves without removing cable from or through any other handling system components. The cantilever design also permits greater freedom in configuring the traction winch system in a range of horizontal to vertical positions to optimize available deck space.

By canting the sheaves in relation to each other, each sheave is positioned to facilitate a smooth transfer of cable between grooves of the two sheaves. This relative positioning eliminates twisting and/or chafing of the cable that might be associated with groove transfer. Figure 4 shows two views; the left view is looking aft or overboard from the storage winch. The right view is the same set of sheave viewed slightly from the side.

Figure 4



A properly designed traction winch system also includes independently driven traction sheaves. Independent sheave drives compensate for sheave machining variations and sheave groove wear by providing the same relative surface speed.

Since today's umbilicals are becoming more sophisticated and expensive, the emphasis should be on protecting the umbilical. In the past, some designers used hardened groove material to minimize or eliminate groove wear. This not only lowered the coefficient of friction but also increased wear on the armor wires. By using softer materials and allowing independent sheave speeds, groove wear is insignificant and armor wire life is greatly enhanced.

4.0 LEVELWINDS

In the event that overboarding devices are located in close proximity to the winch, the resulting fleet angles may require a significant cable wrap angle around levelwind guide rollers. As a general rule, guide rollers do not maintain the cable manufacturer's minimum bend diameter while accommodating these various fleet angles.

For example, in order to maintain the cable manufacturer's minimum bend requirements, a 40-inch minimum bend diameter could be maintained in a conventional drum winch with levelwind guide rollers only if the rollers had an outside diameter equal to 40 inches.

A right angle levelwind provides the dual benefit of maintaining the required cable minimum bend diameter while further optimizing deck space.

The levelwind is used to fairlead cable from the traction winch through a sheave assembly integrated to the levelwind and onto the storage winch drum at a right angle. The levelwind sheave maintains the manufacturer's minimum bend diameter of the cable under low tension with no change in fleet angle. As a result, the use of a right angle levelwind sheave has essentially eliminated the need for guide rollers in a levelwind.

5.0 APPLICATION SUITABILITY OF A TRACTION WINCH SYSTEM

When considering the use of a traction winch system, the following factors should be examined:

a) Optimum operating depth
b) Length of cable required
c) Cable composition
d) Cable breaking strength
e) Minimum bend diameters of cable at 0%, 25% and 50% of cable breaking strength
f) Total weight of cable and payload in seawater
g) Drag coefficient, if applicable
h) Anticipated line pull and line speed requirements
i) Variations in dynamic loads resulting from operations in high sea states or frequent changes in ship speeds

j) Winch drum brake requirements

Although a number of the items listed above are a function of operating depth, priority should be assigned to the optimum line pull requirements and/or winch braking capacity relative to the cable breaking strength. The duty cycle of the particular application at hand should also be examined to determine the relationship between total operational time vs. time spent at maximum line pull when approaching 25% to 50% of cable breaking strength.

Cable length should be reviewed not only from the standpoint of the total cable weight in seawater and the resulting impact on line pull, but also the levelwinding ability of cable, particularly at longer lengths. Storage behavior properties of cable under high tension should also be reviewed.

It should be re-emphasized that high line pull alone should not necessarily be viewed as the sole criterion in the consideration of a traction winch system. As operational line pull and/or winch braking capacity approaches 25 to 50% of cable breaking strength, the comparison becomes significant.

6.0 ECONOMIC JUSTIFICATION OF TRACTION WINCH SYSTEMS

Associative umbilical and payload costs will require winch and handling system to be further refined with increasing attention to cable preservation by adapting to the specific needs of individual customers.

As the ocean industry continues to work at greater depths, vehicle/umbilical design and subsequent capital expenditures will continue to advance in support of more complex operations. Increasing applications for fiber optic cable, as an example, can result in typical costs ranging from $30.00 US per meter for standard 3 fiber-3 power 17mm diameter armored cable to $130.00 US per meter for 6 fiber-38mm diameter Kevlar jacketed umbilicals. Depending on cable length and related costs per meter, traction winch systems may represent a small percentage investment relative to the total cable cost.

Traction winch systems can extend the life of a cable and may allow cable to be used at tensions considerably higher than normal.

As umbilical lengths increase, cable heating concerns require greater awareness. Traction winch systems may allow a cheaper alternative in managing heat problems by allowing cable to be stored on larger drums with fewer layers under low tension.

7.0 BASIC DESIGN CRITERIA FOR A TRACTION WINCH SYSTEM

In the past, a general rule of thumb for sheave diameters was to use a ratio of sheave diameter to cable diameter of 40:1. With the advent of deeper tow systems and the desire to explore all ocean depths, cable lengths have increased and with it the loads placed on the cables. It is not uncommon to load 12,000 meters of .680 inch coaxial or power optic cable onto a winch system. The in-water weight of the cable added to the payload and drag coefficients now have these cables operating at loads as high as 50% of breaking strength.

Simply increasing the size of the cable leads to diminishing returns as a major portion of the load is the weight of the cable. This has lead winch designers and cable experts to look for ways of extending the safe operating loads of existing cables. Cable testing using a larger bend ratio of 80:1 indicated that cable life was acceptable when these larger sheaves were used with high tension loads. Another interesting find was that some fiber optic cables suffer failures from storage at high tensions. Traction winch systems using low tension storage offer a solution to this problem.

When calculating the power required for a traction winch system it can be assumed that the power required by the winch system is shared by the traction winch and the storage winch. In other words, if a total of 100 horsepower is required to lift a load, then 90 could be used by the traction winch and 10 by the storage winch. The same holds true for line pull. In a system with a total line pull of 20,000 pounds, the traction winch could provide 18,000 pounds of line pull and the storage winch 2,000 pounds of line pull.

When designing a traction winch system, the drive train for the storage winch is especially critical. If the torque characteristics and response time of the drive train are not optimized, then dangerous conditions can exist. Slack forming between the traction and storage winch, excessive line pull from the storage winch during payout and insufficient line pull by the storage winch during haul-in are all typical results.

8.0 WINCH POWER CALCULATIONS

A simple formula for calculating power required by a winch is:

Horsepower = (line speed in Ft/Min x line pull in pounds)/33,000

Example: A typical deep tow traction winch system requires a line pull of 20,000 pounds at a speed of 200 feet per minute. The mechanical horsepower at the winch system is (200 x 20,000)/33,000 = 121.21 HP. Typical efficiencies of modern hydraulic winch systems is approximately 70% so 121.21/.70= 173 HP. The closest electric motor to this size is 200 HP. Final design would attempt to provide slightly higher performance to utilize all of the available power.

One of the benefits of a traction winch system is that performance is the same regardless of the amount of cable paid out since line speed and line pull is not affected by the amount of cable paid out as it is with a conventional single drum winch.

Most traction winch systems are either electro-hydraulic or diesel-hydraulic. It is possible to design an all electric system however a minimum of three electric motors would be required and packaging difficulties could make the overall design unwieldy.

9.0 DRUM AND GROOVE DESIGN

Early traction winch designs primarily used a single drive powering both of the traction sheaves. Because of machining tolerances and varying cable elongation, the cable was forced to slip on one of the sheaves. This caused either accelerated wear on the sheave or the cable, whichever was softer. With today's expensive cables, it is not an option to sacrifice the cable to save the sheave. Independent, balanced torque drives for the traction sheaves alleviated this problem. Softer sheave material resulting in a higher coefficient of friction and sheaves that can turn at different speeds from each other greatly eliminate the wear problems. Some early designs used "V" or modified "V" grooves to increase the coefficient of friction when using very hard sheave material. This caused deformation of the cables and with today's fiber optic cable is unacceptable.

When designing a traction system, the designer must first determine what the maximum line pull of the system needs to be. Next, what is the desired or maximum storage tension? A coefficient of friction needs to be assumed – usually greased steel on steel. The Machinery Handbook, 24th Edition, gives a coefficient of friction for lubricated steel on steel of .16 and just to be conservative, we will use .10 in the sample calculation. This tends to be the worst case and by default the safest assumption.

Now to determine the number of grooves in the sheaves, we use the following equation: $\ln(T_1/T_2)/\mu=\theta$

Where:

ln=natural log

T_1= high tension leg, in this case 20,000 pounds

T_2= low tension leg, in this case 2,000 pounds

μ = coefficient of friction, in this case .10

θ = sheave radians of contact

$\ln(20{,}000/2{,}000)/.10 = 23.025$ radians

or 23.025/6.28 = 3.66 total wraps around the sheaves. Rounding up this indicates that a minimum 4 grooves in each sheave need to have 180 degrees of contact.

10.0 CONCLUSION

Traction winch systems should be considered as an economically viable cable handling option when operational line pull approaches 25% to 50% of cable breaking strength and/or brake ratings meet or exceed cable breaking strength. As operating depths and related cable lengths increase, traction winch systems are particularly attractive as these operating parameters converge.

Ocean industry users should look beyond acceptance of the traction winch concept to ensure that the selected traction winch design addresses the issues of sheave construction, sheave relative position and sheave drives.

The hallmark of a properly designed traction winch system is the ability to apply operating performance that is consistent throughout the cable scope, regardless of length.