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Attorney Docket No. 97879

AN IMPROVED FAIRLEAD FOR A TOW CABLE HANDLING SYSTEM

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to an improved fairlead for a tow cable handling system and more particularly to a fairlead that protects the handling system components even when the tow cable breaking strength exceeds the rated strength of the handling system.

(2) Description of the Prior Art

[0004] It is known in the art that ships employing tow cables require a cable handling system that is rated for a failure load higher than the breaking strength of the cable being used. This is because, in the unlikely event that a tow cable snags, cable tension can quickly approach the breaking strength of the cable. Ideally, an overstressed tow cable will break at mid-span and not tax the handling system. A less desirable alternative is a case where a tow cable does not reach breaking strength because the winch shaft, the winch foundation or the fairlead foundation of the handling system first fails due to excess cable tension load.

[0005] Cable diameter is a major factor in towed sonar system design. A small diameter tow cable (i.e., less than 0.75" diameter) usually cannot achieve the depth needed for surface ship towed sonar system operations. A larger diameter cable will tow at an increased depth because as the cable diameter increases, the weight of the cable in the water increases faster than the hydrodynamic drag of the cable. However, the breaking strength of the cable, and the corresponding handling system load rating requirements, also increase with cable diameter. For example, a typical 1" diameter tow cable with a cross-sectional area of 0.7854 in^2 typically has a breaking strength of 40,000 lb or more. This breaking strength often requires a winch rated at 60,000 lb or greater in order to include an acceptable factor of safety, 1.5 in this case. The supporting deck and underlying foundation also need to have the same or a higher load rating.

[0006] Attempting to retrofit a 1" diameter cable to a legacy handling system designed for a 0.8" diameter cable in order to permit greater tow depth can create problems - even if the handling system winch has enough volume to accommodate the new larger cable. A typical 0.8″ diameter cable has a breaking strength of 25,600 lb. The handling system for the 0.8″ diameter cable would be designed to incorporate a typical breaking strength 1.5 factor of safety load rating of 38,400 lb. The 40,000 lb breaking strength of the new 1″ diameter cable will exceed this handling system rating which in most cases is fixed and cannot be changed, thus risking catastrophic failure of the handling system upon the occurrence of a cable snag.

[0007] One known approach to overcome the excessively high cable breaking strength problem involves simply letting the cable unreel freely from the winch if a cable snag occurs. Unfortunately, with this approach, the rotational inertia of the typical winch usually prevents the winch from speeding up fast enough to relieve the momentary tow cable tension surge. The time required to unlock the winch or release the brake is also non-negligible, and would require automated detection of any tension surges in order to preclude a delayed response.

[0008] Other known approaches to resolving the tension forces caused by a snag are to use a guillotine-type mechanism to quickly cut the cable mechanically or to employ a cutting torch. However, a typical tension surge occurs so quickly (typically in a 200 millisecond spike) that the response time of the cutter or torch system may not be fast enough. The tension surge duration is related to the difference in speed between the ship and the relatively immovable object snagging the cable, the cable length, and the cable stiffness. Any change in cable tension propagates along the cable at 5000 meters per second.

[0009] Guillotine mechanisms have been used previously in conjunction with helicopter-deployed dipping sonar systems that employ long synthetic cables of small diameter (typically 0.5″ or less). Several factors make a guillotine approach feasible for such dipping sonar systems: (1)synthetic cables stretch more than steel cables before breaking; (2)a small diameter cable with low stiffness exhibits more stretch; (3) a long cable length is employed with dipping sonar systems increasing total stretch, and (4) the essentially stationary helicopter deploying the system allows both the stretch and the tension to increase slowly in the event of a cable snag.

[0010] Another common approach is to employ a mechanical fuse-like weak link that is incorporated into the tow cable and is designed to break at a tension lower than the breaking strength of the cable. It is a better approach than using a guillotine type device or depending on an unreeling winch, but a snag could still potentially occur above the fuse placement.

[0011] Whatever object snags the tow cable, the object will tend to slide backward along the cable, stop, and then generate a tension surge from that point back to the cable handling system on board the tow ship. The most likely snag stopping point along the cable is the distal end of the tow cable. What is needed is a rapid means to prevent the cable tension surge from damaging the tow cable handling system components.

SUMMARY OF THE INVENTION

[0012] Accordingly, it is a general purpose and primary object of the present invention to provide a system to rapidly reduce the tension load on a tow cable by quickly cutting the cable strength members if the towed sonar system tow body encounters a snag.

[0013] It is a further object of the present invention that the cutting device be simple, reliable and capable of inclusion in a fairlead.

[0014] It is a still further object of the present invention to have the invention be capable of being backfit on existing tow cable winch systems in conjunction with larger diameter, heavier tow cables to achieve greater towed sonar system tow body depth.

[0015] The objects described above are accomplished with the present invention by providing an improved fairlead that protects the tow cable handling system when the tow cable breaking strength exceeds the rated tension load strength of the handling system. The fairlead is positioned in collinear arrangement between the bellmouth and the winch of the tow cable handling system. A cable guide slot passing through the fairlead acts to position the tow cable somewhat higher than the height of the winch release point and bellmouth entry point to maintain the appropriate down slope for the tow cable as the cable exits the fairlead at both ends. The guide slot is defined by a hemispherical portion at the top tapering inwardly to a groove extending downward from there. Near the bottom of the tapered groove, at the aft end of the fairlead that is nearest the bellmouth is a fixed cutting device hereafter referred to as a "cutter".

[0016] Under normal tow tension, the cable rides in the upper hemispherical portion of the groove well above the cutter. But, if the cable tension suddenly increases due to a snag, the resulting downward force from the snag drives the cable into the groove where the cable strength members are cut by the cutter and the tow cable separates before the snag forces reach a level that can damage any of the components of the handling system. The cable portion that is still wedged in position in the groove remains securely held in place by the taper.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 depicts a tow cable handling system including an improved fairlead according to the teachings of the present invention;

FIG. 2 depicts a detailed cross-sectional view of the bellmouth device of **FIG. 1** as shown by the reference lines 2-2 depicted in **FIG. 1**;

FIG. 3 depicts a cross-sectional view showing the outer layers only of a typical tow cable such as used in the system of **FIG. 1**; and

FIG. 4 depicts a partial cross-sectional view of the improved fairlead of **FIG. 1** displaying a tapered groove and an embedded cutter as shown by the reference lines 4-4 depicted in **FIG. 1**.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Referring now to **FIG. 1** there is shown an improved tow cable handling system **10** for use with surface ship towed sonar. The system **10** includes a linear forward-to-aft arrangement of a winch **12** with a tow cable **14** of preselected length and diameter wound about the winch; a fairlead **16** having a top face, a bottom face and forward and aft vertical faces, fairlead **16** being disposed aft of the winch **12** with the bottom face being affixed onto a deck **100**; and a bellmouth **20** inserted through and fixedly attached to a stern bulwark **102**. The fairlead **16** acts as a tow cable guide.

[0019] During deployment and retrieval from the winch **12**; the tow cable **14** next passes through the fairlead, sloping upward at a ten degree angle from the winch to enter the proximal side of the fairlead that is positioned nearest the winch and exiting the distal side of the fairlead at a downward sloping ten degree angle. The winch **12** and the fairlead **16** are each capable of being fixedly attached to a ship deck **100** in a spaced apart relationship. The tow cable **14** continues on from the distal side of the fairlead **16** and is then guided overboard via the bellmouth **20** that provides passage for the cable through an aft bulwark **102**. The fairlead **16** is nominally in-line between the winch **12** and the bellmouth **20** thereby allowing a straight run for deployment of the cable.

[0020] **FIG. 2** depicts a cross-sectional enlarged view of the bellmouth **20** of **FIG. 1**. The bellmouth **20** is a trumpet-like or bell-like opening in the aft bulwark **102** of the ship whose function is to minimize tow cable damage while it passes overboard by maintaining a minimum radius of cable curvature independent of the tow angle of the sonar. The recommended cable curvature radius 'R' for a bellmouth is thirty times the radius of the tow cable **14**.

[0021] **FIG. 3** depicts a partial cross-sectional view showing only the outer layers only of a typical tow cable similar or equal to the tow cable **14**. Alternate tow cables known to those skilled in the art may be used that would be compatible with the cutting operation of the present invention. The outer portion of the tow cable shown includes multiple layers of longitudinal strength members **24** (steel or Kevlar) disposed over a longitudinal core of polymer insulation **26**. The interior volume **28** of the cable **14** typically includes a pre-selected plurality of components in combination (not shown) that are easily compressed, including mostly polymers for water block and insulation, optical fibers and copper wires - as desired for support of the particular tow application.

[0022] **FIG. 4** depicts the sequence that occurs if a rapid cable tension surge is produced by the tow cable **14** snagging. This tension surge generates a downward force 'F' that rapidly moves the tow cable **14** down into tapered groove **30** of the fairlead **16** until carbide cutting tool inserts **32** disposed near the bottom of groove **30** can sever enough of the strength members **24** of the tow cable **14** to enable the remainder of the cable to pull apart at a tension level below the system **10** factor of safety load rating. The groove **30** has a hemispherical top portion of a diameter greater than the diameter of the tow cable **14**. The groove **30** necks down from the diameter of the hemisphere to a very narrow pre-selected width.

[0023] In **FIG. 4**, the tow cable **14** is shown in various stages of deformation (i.e., **14a**, **14b** and **14c**) sequentially as the cable is driven down into the groove **30** by tension force 'F'. The downward motion, guided by the fairlead **16**, causes the tow cable 14 to quickly clamp and then be cut with no delay in response time. The fairlead **16** maintains the required cable down sloping angle in the vertical plane (as shown in **FIG. 1**) being nominally in line with the bellmouth **20** and the winch **12**. It is noted that the tow cable **14** also moves a limited distance in the athwartship direction between the flanges of the winch **12** as the cable unreels. This lateral movement is accommodated in the fairlead **16** by the added space in the upper hemispherical portion of the groove **30**.

[0024] The tension surge drives the tow cable **14** into the tapered groove thereby avoiding any time delay. The moment arm generated by the cable tension makes necessary aft cross-structures (not shown) for fastening the fairlead **16** to the deck **100** in order to increase the moment of inertia of the fairlead structure thus preventing backward rotation of the fairlead **16**. The angle of the tow cable **14** with respect to the fairlead **16** determines the downward force of the cable. For example, if the breaking strength of the tow cable 14 is 40,000 lb and the angle is ten degrees on each side of the fairlead 16, the downward force can approach $F = 2 \times 40000\sin10 = 13,900$ lb.

[0025] The narrowly spaced surface area near the bottom of the groove **30** has at least two embedded carbide tooling inserts **32** designed as a cutter to cut the strength member strands **24**. The aft part of the groove **30**, the end nearest to the bellmouth **20**, contains the cutting inserts **32**; the forward part closest to the winch **12** does not. The tapered groove length from the cutter forward towards the winch serves to clamp the wedged winch side end of the severed tow cable **14** in place.

[0026] The cutting inserts **32** are adapted from known industrial tools used for cutting steel work pieces. A 40,000 lb cable tension and a 14,000 lb downward force will greatly aid the rapid severing of the strength members. Even if the cutting inserts **32** sever only half of the strength members, the remaining cable will break at 20,000 lb instead of at the rated 40,000 lb with the result of protecting the handling system.

[0027] The advantages and new features of the present invention are: the improved fairlead structure can be a replacement unit for legacy handling systems; the ability to safely retrofit a larger diameter cable to a legacy handling system permits greater cable tow depth even if the legacy system safety factor load rating does not exceed the cable breaking strength; the cable is clamped and cut at the speed of the tension surge before significant structure motion can occur, even without welding the fairlead to the deck; and the tapered groove in the fairlead holds the remaining cable thereby preventing the cable from "snapping back" after the cable is cut.

[0028] What has thus been described is an improved fairlead that protects the tow cable handling system even when the tow cable breaking strength exceeds the rated tension load strength of the handling system, the fairlead being positioned in collinear arrangement between the bellmouth and the winch of the tow cable handling system.

[0029] A cable guide slot passing through the fairlead acts to position the tow cable somewhat higher than the heights of the winch release point and the bellmouth entry point to maintain the appropriate down slope for the tow cable as the cable exits the fairlead at both ends. The guide slot is defined by a hemispherical portion at the top that tapers inwardly to a groove extending downward. Near the bottom of the tapered groove, at the end of the fairlead nearest the bellmouth, is a fixed cutting device.

[0030] Under normal tow tension, the cable rides in the upper hemispherical portion of the groove well above the cutting tool. But, if cable tension suddenly increases due to experiencing a snag, the resulting downward force from the snag drives the cable down into the groove where the cable is cut by the cutting device and separates before the snag forces reach a level that can damage any of the components of the handling system. The cable end that is still in the groove is securely held in place by the groove taper.

[0031] Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example: the depth of the tapered groove can be varied; the number of cutting blades used, the depth in the groove and the angle of the blades are design choices to accommodate varying situations; the fairlead may be fastened to the deck by other means than welding; a torch can be used as a backup cable cutting device if desired and would be activated immediately when the cable clamps itself; and a backup protective cage may be constructed using many shapes and materials if so desired.

[0032] In light of the above, it is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

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AN IMPROVED FAIRLEAD FOR A TOW CABLE HANDLING SYSTEM

ABSTRACT OF THE DISCLOSURE

A handling system with an improved fairlead is provided for protecting a tow cable wherein the cable breaking strength exceeds the system-rated tension load; the fairlead being positioned collinearly between the system bellmouth and winch. A guide slot passes through the fairlead positioning the cable higher than the winch release point and bellmouth entry point, maintaining the cable down-slope as the cable exits the fairlead. The slot has a hemispherical portion tapering inward to a groove extending downward. Near the groove bottom, at the fairlead end nearest the bellmouth, is a cutting device. Under tension, the cable rides in the hemispherical portion of the groove. If tension suddenly increases from a snag, the resulting force drives the cable down into the groove where the cable is cut by the device, separating before the force damages the system. The constrained cable end is securely held in place by the taper.

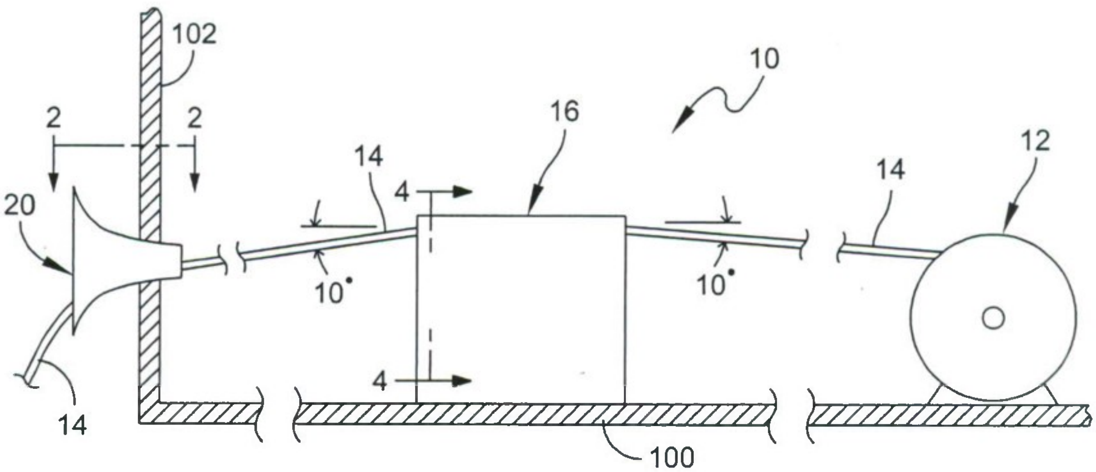

FIG. 1

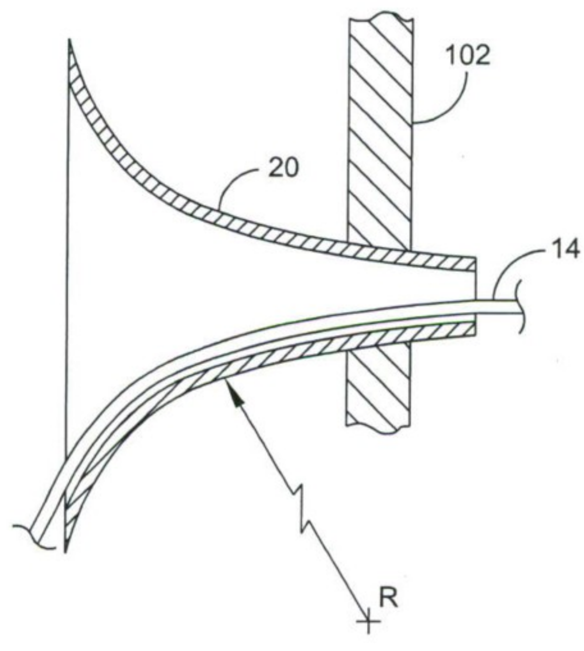

FIG. 2

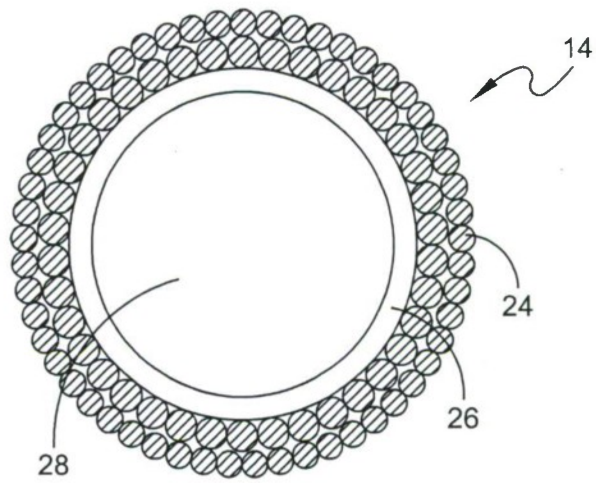

FIG. 3

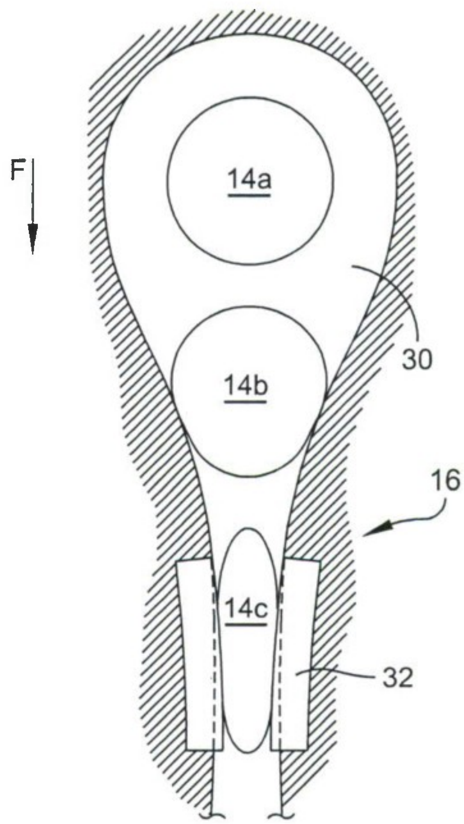

FIG. 4