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Inventor An-Keun Peter Lee
            Michael R. Williams
            Todd E. Whitaker

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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 therefore.

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS
This patent application is co-pending with one other patent application entitled THIN-LINE TOWED-ARRAY FORCE MEASUREMENT APPARATUS AND METHOD (Attorney Docket No. 78871) by the same inventor as this application.

BACKGROUND OF THE INVENTION
(1) Field of the Invention
The present invention relates generally to fat-line towed-arrays, and more particularly to an apparatus for measuring the force applied to fat-line towed-arrays during flushing cycles.
(2) Description of the Prior Art
Submarines deploy fat-line towed-arrays using a process known as flushing, wherein water is pumped into the fat-line stowage tube to exert pressure upon and hence deploy the fat-line towed-array. Deployment success can be determined by measuring the flushing water force applied to the fat-line towed-array.
Since effective deployments are critical to successful submarine missions, it is essential to maintain a method to evaluate the flushing mechanics and effectiveness. There is currently no reliable method to evaluate a submarine's flushing procedure. What is needed is an apparatus and method that measure and evaluate the flushing process effectiveness.

SUMMARY OF THE INVENTION

It is a general purpose and object of the present invention to provide a means of measuring the effectiveness of a submarine's flushing procedure for fat-line towed-arrays. It is a further object to use a combination of tension and bending sensors and measurements to evaluate the flushing system. It is another object to provide such tension and bending sensors as modules that can be connected to a fat-line towed-array. It is yet a further object to integrate the sensors with a tow cable for communication to a data processing system for evaluation.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

These objects are accomplished with the present invention by sensors in the standard fat-line towed-array configuration at the typical telemetry positioning. Tension sensors located within a modified fat-line towed-array bulkhead measure axial tension applied to the front of the towed-array during the flushing cycle. Bending sensors mounted further downstream along the fat-line canister walls, measure the bending load during the flushing
cycle. The sensor outputs are encoded and digitized before being transmitted through a tow cable for further data conditioning and processing. The tension and bending sensor data provide information to evaluate the force exerted on the fat-line towed-array thereby allowing a measure of the deployment capability and effectiveness.

BRIEF DESCRIPTION OF THE DRAWINGS

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 like reference numerals refer to like parts and wherein:

FIG. 1 provides a diagram of the general layout of the tow vessel, towed array and tow cable;

FIG. 2 shows a cross-sectional view of the sensor configuration contained within the fat-line towed-array; and

FIG. 3 shows a view of the tension shaft for sensing tension applied to the bulkhead.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a basic system configuration. The measurement sensors are physically located within the fat-line towed-array 10, at the fat-line towed-array end nearest the nose cone assembly 12. The tow cable 14 provides an electrical connection to signal conditioning electronics 16.
that amplify and filter signals, and interface to a computer 18. Electronics 16 and computer 18 are located on a tow vessel 19 joined to tow cable 14. The computer 18 collects the system sensor data and performs the final processing to evaluate system performance.

In FIG. 2 there is shown a redesigned bulkhead 20 incorporating the tension sensors and bending sensors. The bulkhead 20 joins two sensor canisters at the bulkhead coupling 22. The coupling 22 is the same width as the first canister wall 24 and second canister wall 26, thereby allowing the bulkhead 20 to fit inside the towed-array sectional elements while allowing a strong coupling between the two sections. Forward bulkhead portion 28 is cylindrical with a tension shaft mounting cylinder 30 having a smaller diameter extending aftward. A forward bulkhead cavity 32 is formed within the main body of the forward bulkhead portion 28, and a tension shaft aperture 34 formed through the shaft mounting cylinder 30. Screw 36 to the right of the coupling 22 secure the first canister wall 24 to forward bulkhead portion 28. Aft bulkhead portion 38 is a hollow cylindrical structure having a forward bulkhead receiving cavity formed therein. Upon assembly, the forward bulkhead receiving cavity receives the shaft mounting cylinder 30. The second canister wall 26 is secured to the aft bulkhead portion 38 using screws 40 aft of the coupling 22. Double O-rings 42 are provided in slots formed in the forward bulkhead portion 28 and the aft bulkhead portion 38 on either side of the coupling 22 to prevent water leakage into the canister walls 24, 26. O-rings 44 prevent
liquid from entering the bulkhead between the forward bulkhead portion 28 and the aft bulkhead portion 38. The forward bulkhead portion 28 contains an alignment key 46 or pin that is inserted into a slot in the aft bulkhead portion 38 to prevent the aft bulkhead portion 38 from rotating; however, the forward bulkhead portion 28 and the aft bulkhead portion 38 are not otherwise attached.

A disk shaped end cap 48 is secured to the aft bulkhead portion 38 using a screw 50. End cap 48 has a threaded tension shaft receiving aperture 52 formed at its center.

A tension shaft 54, shown in more detail in FIG. 3, extends through the first bulkhead portion 28 shaft mounting cylinder 30 to the tension shaft receiving aperture 52. The tension shaft 54 allows sensor mounting for measuring tension in orthogonal directions between the two bulkhead sections. The tension shaft 54 is a single unit with a head 56, a sensor mounting section 58, a threaded section 60, a hollow core 62, feed apertures 64, and a decoupling groove 66. The tension shaft head 56 can be circular but it can also be square or hexagonal in cross-section to allow the use of a wrench for fastening. Hollow core 62 is formed in the center of shaft 54 and traverses the entire tension shaft length. Preferably core 62 is cylindrical in shape to avoid chafing cables running therethrough. The sensor mounting section 58, adjacent to the head 56, has a square cross-section with smooth surfaces on all sides for mounting tension sensors 68. Because the mounted sensors 68 provide outputs for recording, each side of the rectangular sensor mounting section 58 contains
feed aperture 64 in communication with the hollow core 62 for
transporting wiring.

A decoupling groove 66 in the tension shaft 54 decouples the
sensor mounting section 58 from the circular threaded section 60.
The threaded section 60 maintains a circular cross-section with
threads for securing the tension shaft 54 to the end cap 48
threaded tension shaft receiving aperture.

The tension shaft 54 is mounted with tension shaft head 56
flush against the tension shaft mounting cylinder 30 and the
sensor mounting section 58 extending into the tension shaft core
62. Sensor mounting section 58 does not contact the tension
shaft mounting cylinder 30 in order to prevent interference with
the sensors 68.

The forward bulkhead portion 28 and end cap 48 are separated
by a space 70 that aligns with the tension shaft decoupling
groove 66, and the forward bulkhead portion 28 and end cap 48 are
not otherwise connected or attached.

Bending sensors 72 and electronics 74 are positioned within
the measurement module canister. The bending sensors 72 are
located on the second canister wall 26 where they measure the
towed-array element bending caused by the fluid flow. The
bending sensors 72 are electrically coupled by wire 76 to the
sensor electronics 74. Electronics 74 are also coupled by wire
78 to the tension sensors 68. The sensor electronics 74 digitize
and encode the sensor measurements for transmission through cable
80 to the tow cable 14 as shown in FIG. 1, to the signal
conditioning unit 16.
The flushing fluid travels in the direction shown 82, and
exerts pressure on the nose cone assembly that is measured by the
tension sensors 68. The flushing liquid applies stress to the
nose cone assembly and fat-line towed-array sections, and as the
flushing liquid passes along the sides of the fat-line towed-
array sections, tension is applied to the towed-array sections,
including the two sections joined by the modified bulkhead. With
the first fat-line towed-array section connected to the forward
bulkhead portion, and the second fat-line towed-array section
connected to the end cap, the tension caused by the fluid flow is
translated to the bulkhead sections and hence the tension shaft
54 that joins the two bulkhead sections. Measurement devices
located on the tension shaft 54 record the tension applied to the
bulkhead sections.

In a preferred embodiment, tension sensors 68 and bending
sensors 72 use strain gages as the active elements. For
measuring tension, a single strain gage is attached to each of
the four sides of the rectangular tension shaft sensor mounting
section 58, thereby comprising two orthogonal wheatstone bridge
configurations with two strain gages in each wheatstone bridge,
providing two tension differential outputs to the sensor
electronics. The strain gages are attached using epoxy. The
bending sensors 72 are embodied as four additional strain gages,
wheatstone configured to measure bend in two orthogonal
directions. The bending sensors 72 are mounted on the interior
walls of the second measurement module element using epoxy. Two
strain gages comprise the first wheatstone bridge sensor, while a
second strain gage pair form the orthogonal wheatstone bridge.
The bending and tension sensors utilize the tension shaft hollow
core 62 to transport the strain gage wiring 78 to the standard
bulkhead connector fixture and hence the sensor electronics 74.
The sensor electronics digitize and encode the tension and bend
measurements for transmission to the signal conditioning
electronics 16 that amplify and filter the digitized
measurements. The computer 18 processes the tension and bend
measurements for various fluid flow rates to determine the fluid
effectiveness for fat-line towed-array deployment.

The advantage of the present invention over the prior art is
that the disclosed invention provides a novel apparatus and
method of measuring the effectiveness of fluid flow to deploy
fat-line towed-arrays.

What has thus been described is an apparatus for measuring
the force applied to the fat-line towed-array during a flushing
cycle. Tension sensors reside in a modified bulkhead structure
to measure axial tension applied to the front of the fat-line
towed-array during the flushing cycle. Bending sensors mounted
further downstream along the fat-line canister interior walls
measure the bending load during the flushing cycle. The sensor
outputs are encoded and digitized before being transmitted
through a tow cable for further data conditioning and processing.
The tension and bending sensor data provide information to
evaluate the force exerted on the towed-array, thereby allowing a
measure of the deployment capability. Measurements taken at
various fluid flow rates provide data regarding deployment effectiveness.

Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example, although strain gages were used as the sensors in the example provided, other sensing elements may be utilized. The strain gages may be configured differently than the wheatstone configurations described, and more than two groups of tension and/or bending sensors may be utilized. Although the strain gages were secured using epoxy, other adhesives or methods may be used. The digitizing and encoding electronics may be located within the fat-line towed-array canister, or at another location. There are many different bulkhead configurations that can be modified for the tension measurements. The procedure for securing the sensors to the tension shaft or canister wall can vary and is application dependent. Although the bulkhead plates described in the preferred embodiment were designed of aluminum, other materials may function equivalently. The signal conditioning functionality may be incorporated in the computer or in the sensor electronics.

In light of the above, it is therefore understood that the invention may be practiced otherwise than as specifically described.
FAT-LINE TOWED-ARRAY FORCE MEASUREMENT APPARATUS

ABSTRACT OF THE DISCLOSURE

An apparatus for measuring tensile and bending forces applied to a fat-line towed-array. Tension sensors are configured within a modified fat-line towed-array bulkhead to measure axial tension applied to the front of the fat-line towed-array, while bending sensors mounted further downstream along the fat-line canister interior walls, measure the bending load. The sensor outputs are encoded and digitized before transmitted through a tow line for further data conditioning and processing. The tension and bending sensor data provide information to evaluate the force exerted on the towed-array, allowing a measure of the deployment capability. Measurements taken at various fluid flow rates provide data regarding deployment effectiveness.