

Elastic mooring of navigation buoys in shallow water

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Recent improvements of navigation buoys have made wear of the mooring chain one of the weakest point of the complete system. The use of an elastic mooring for navigation buoys - common practice for over 40 years in the case of wave measuring buoys - constitutes a substantial improvement in life expectation. In the case of shallow water, the severe requirement on the maximum elongation of the elastic mooring is met by the combination of natural rubber and bollard terminals.

Introduction

With increasing life time of navigation buoys, it is the wear of the mooring chain that mainly determines the service interval for these systems. Grinding by sand contributes substantially to this chain wear. The sand grains get between the chain links when the mooring line is slack, and do their damage when it is tightened again. The ongoing wave movement causes the mooring line to be alternately under tension and without tension. Although tides and currents distribute this wear somewhat over the chain, it is better to prevent this wear altogether. A way to reduce the grinding is by keeping the mooring line continuously tight, thus keeping the grains out of the link spacings. This is achieved by putting in an elastic cord in the mooring line.

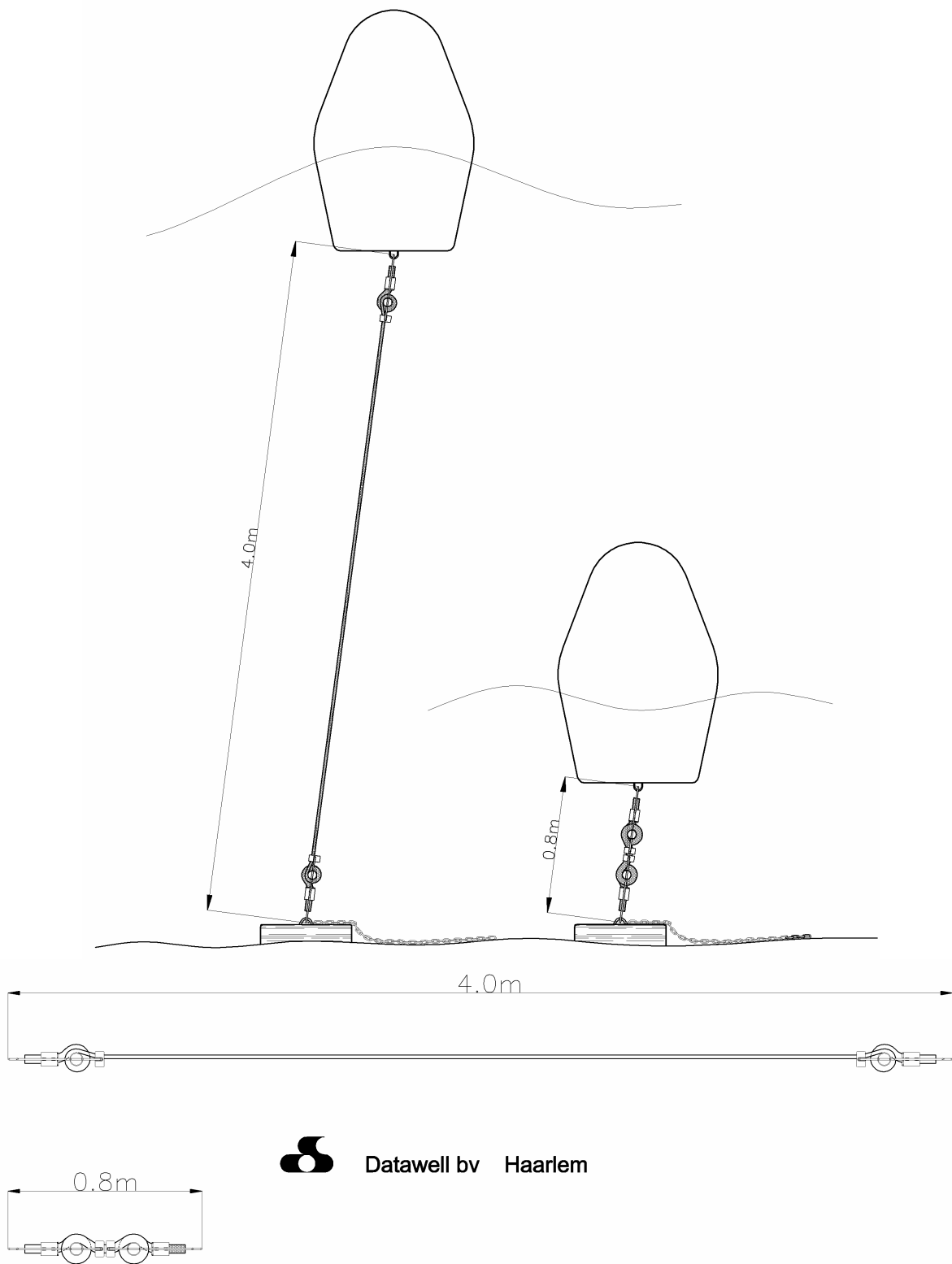
Problem of shallow water

Designing an elastic cord mooring is a challenge especially in shallow water with a relatively large tidal amplitude. In these circumstances, the ratio of the maximum cord length - needed to keep the buoy visible at high tide - and the minimum cord length - needed to keep the line under tension at low tide - is very large. This large ratio constitutes a requirement on the maximum elongation of the elastic cord.

In order to discuss this problem in quantitative terms, we introduce the symbol λ , denoting the ratio of the actual cord length at any moment and the initial cord length when being unstressed. An elongation of 100% is thus indicated by $\lambda = 2$, a 200% elongation by $\lambda = 3$, etc.

The maximum elongation of an elastic cord is denoted by λ_{\max} . When we indicate the length ratio required by the circumstances as λ_{req} , the problem is reformulated as finding a cord mooring for which $\lambda_{\max} > \lambda_{\text{req}}$.

Let us consider a typical shallow water situation having a low tide depth of 2.5 m, a tidal cycle of 3.5 m and a maximum current of 1 m/s. In addition, a maximum wave height in the range of a few metres is assumed. In these circumstances, λ_{req} is about 4. Traditional overbraided rubber cords cannot meet this requirement, since their λ_{\max} is only 2 [1]. A rubber cord with a loosely woven overbraid, sometimes used in open sea [2], does have a λ_{\max} of 4, however, in this case the wear problems are not solved but transferred to the rubber/braid strangles.



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Figure 1 A bare cord of natural rubber terminated by special bollard terminals.

Solution

The proper choice in this situation is a bare cord of natural rubber, terminated by special bollard terminals, see Fig. 1. When terminated by the standard Datawell rubber cord terminals, the maximum elongation of the rubber itself is circa 4. However, since the bollard of the terminal holds a certain length of cord - that, when stressed, slips from the bollard and adds up to the cord length -, the effective λ_{\max} of the combination of cord and terminals is larger than this 4, and can in fact be as large as 5. The shorter the rubber cord is, the stronger is this positive bollard effect.

The elastic mooring line described above is basically a shortened version of the standard Datawell rubber cord used for over 40 years to moor (Directional) Waveriders and Wavecs [3]. Basically these buoys are motion sensors. They become wave sensors when enabled to follow the orbital waves movement. For this reason, an elastic cord is incorporated in the mooring line of these buoys. The size of the wave buoys ranges from 0.7 m diameter (spherical) to 2.5 m diameter (discuss shape). Standard lengths of the rubbercord are 15 and 30 m of rubber with a hardness of either 45 or 60 Shore A, depending on size of the buoy and required specification of the wave buoy.

The elegance of the Datawell rubber cord design is its simplicity. It consists of an arbitrary length of rubber and two stainless steel terminals which are easily mounted and removed from the rubber cord. Since the rubber cord is bare and solid, wear due to sand is principally impossible. Also, no fouling is encountered, since it cannot stick to the surface of the continuously oscillating cord. Finally, the fouling of the stainless steel bollard is prevented by the piece of the rubber cord at the terminal moving on and off the bollard.

The flexible mooring for navigation buoys serves basically the same purpose as the mooring for wave buoys: allowing the buoy to follow as much as possible the wave motion without getting off location. Often the elastic cord has been promoted by suppliers with the argument of shock absorption. However, also in properly chain-moored buoys no shocks show up. The craftsmanship and experience of the local light house authorities help them in determining the minimum chain length long enough to avoid the chain being tightly stretched between buoy and mooring stone.

This minimum chain length will always exceed the length of an optimally designed elastic mooring, making the latter preferable in terms of precise localization. It also suggests that the flexible mooring, though perhaps more expensive per unit length, could well be the most profitable when comparing complete designs. Apart from this reduction of initial expense, it is expected that inspection, maintenance and retrieval will occur less frequently, thus making the elastic mooring the more economical one.

Measurements and Results

The rubber cord mooring has proved itself for the Wave-buoy over the past decades. In order to check the suitability for navigation buoys, the Dutch light house authorities have performed extensive experiments over the past years. With increasing confidence in the performance of the rubber cord mooring, a chain/rubber comparison experiment was performed.

**Rubber Cord, Maximum Mooring Force
18 September 2000 - 25 October 2000**

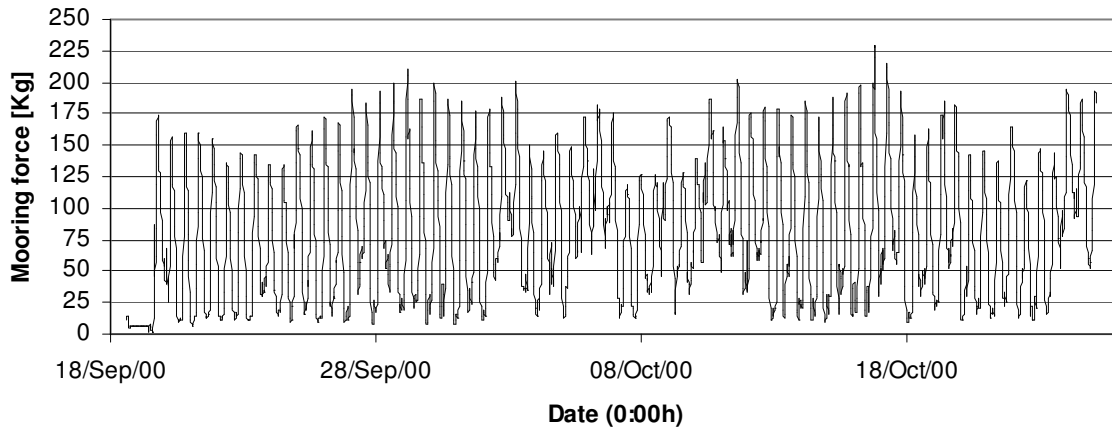


Figure 2 A Rubbercord: 1.5 m

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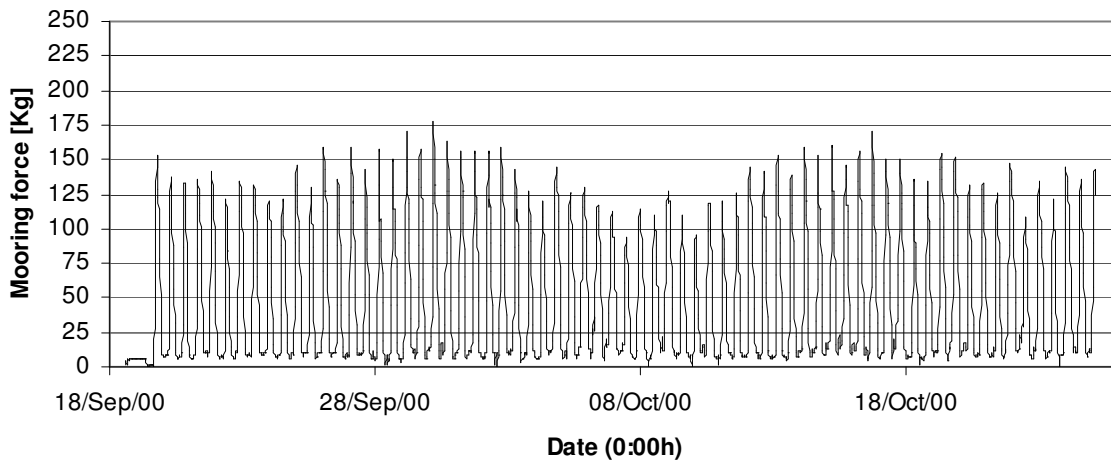


Figure 2 B Rubbercord: 1.5 m

**Chain, Minimum and Maximum Mooring Force
18 September 2000 - 25 October 2000**

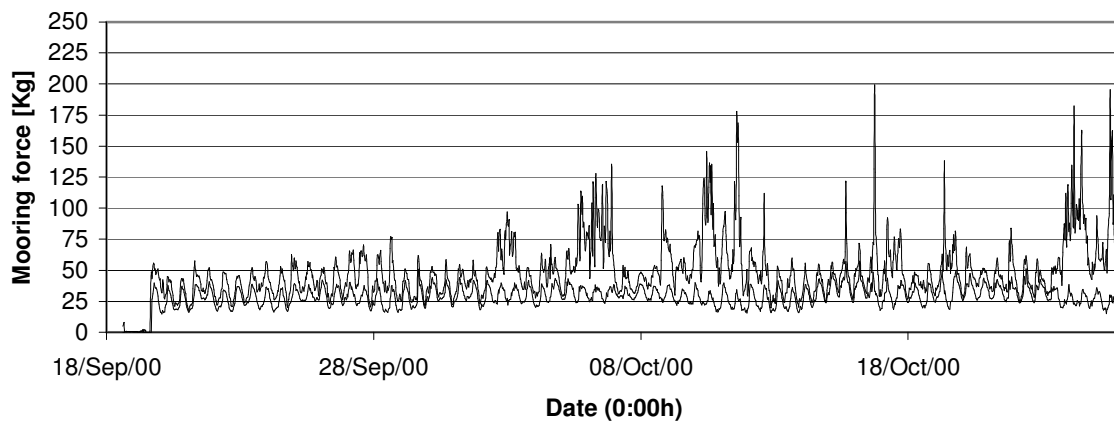


Figure 3 Chain: length 20 m, weight 8.8 Kg/m

For figures 2AB and 3: Mooring force of a 1.8 m diameter light buoy. Water depth: minimal 3.7 m; tidal cycle: 4 m. Minimum/maximum is determined over half hour periods (1 Hz sampling).

Two identical buoys (1.8 m diameter) are moored close to each other, (minimum water depth 3.7 m, maximum tidal cycle: 4m, maximum current: 2 kn). One buoy is moored using chain (length 20 m, weight: 8.8 kg/m), the other buoy is moored using rubber (length 1.5 m 45 Shore A, standard Datawell terminals). Both buoys had a load cell plus data logger in the mooring line. During one year, the forces in both systems were monitored: every second the force was measured, and the minimum and maximum value of each half hour was stored.

Some typical autumn results are shown in Figures 2ab and 3. The weather in the shown time span is a combination of mild autumn weather, and a severe storm.

All curves show tidal oscillations. In the rubber cord mooring, the force increases with high tide due to extra elongation. In the chain mooring, the force increases since more chain is lifted from the seabed. One can see that the force of the rubber cord is typically much larger than the force of the chain mooring. As expected, the rubber cord is kept under tension, avoiding wear on the shackle, mooring eyes, and terminal connections.

In the first half of the figure, smooth oscillations in the chain mooring can be observed, whereas in the storm period some peaks loads are observed. These peaks however do not exceed the forces on the rubber cord.

Handling

A typical weight reduction by a factor 10 or 20 compared to a chain mooring makes the handling of a rubber cord mooring system a delight on deck or in store. The rubber cord itself is solid, and made of natural rubber known for its excellent properties. Although life on the sea can be rough, no rubber cord has ever been damaged on a ship.

For safety reasons, Datawell's policy has always been to have no force on the elastic part of the mooring when retrieving a buoy. The Dutch lighthouse authorities have made the same decision. Handling procedures varying with circumstances have been developed. In the shallow water situation, two methods have been tested: 1) using a ground chain that is picked up by a drag, 2) with barbed hooks welded onto the terminals. The latter method, still under development, is only suited for single point mooring systems.

Often a kind of safety line is used to limit the elongation of the elastic mooring, and suggesting the retrieval of the mooring stone via the safety line. This has the obvious risk that the unknown state of the mooring gets the full load. Although serious accidents are only expected once in a lifetime, the risk should not be run.

Future

In view of the excellent results of the shallow water situation with relatively small navigation buoys, larger navigation buoys on new locations will be moored with Datawell rubber cord moorings. The experience of thousands of Waverider moorings and hundreds of Wavec buoy moorings, in both near shore and open sea, and with breaking waves and large tidal currents, will be used to moor navigation buoys. Various designs with or without safety-line, with 45 or 60 shore rubber and varying diameter of rubber are considered to make the most successful mooring for navigation buoys.

Conclusion

A proven system for Waveriders has shown to be a reliable mooring for navigation buoys in shallow water as well. Inspection of moored buoy show indeed the expected reduced wear of the metal/metal connections. Since the length of the rubber mooring system is much shorter than the length of the chain mooring, the buoy stays closer to its anchoring. An expected advantage is the increase of the inspection intervals, resulting in a reduction of annual inspection costs.

References

- [1] Datawell Internal report “Omvlechting”, See also ORETECH standard Product Catalogue Oceanography and Geophysics, ENDECO fail-safe mooring accumulator type 996, page 387.
- [2] ORETECH standard Product Catalogue Oceanography and Geophysics, ENDECO fail-safe mooring accumulator type 996, page 386.
- [3] Proceeding of the Conference held at the National Institute of Oceanography 1972, Editor: L. Draper; IOS report NO 145 1982 “Operational Experience with Waverider buoys and their moorings”, by JD Humphery; Datawell Waverider manual, Datawell Wavec manual, Datawell Directional Waverider manual.









