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Predicting the Torsional Response of Large Mooring Chains

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Abstract

The extensive use of chain as an element in multi-component moorings by the offshore industry has led to a requirement to be able to predict the torsional response of chain under a variety of service applications. Chain exhibits some interesting behaviour in that when straight and subject to an axial load, it does not twist or generate any torque. However, if chain is twisted while carrying axial load, or subjected to axial load when in a pre-twisted condition, it behaves in a highly non-linear manner, with the magnitude of the torque dependent upon the level of twist and the axial load. Consequences of this behaviour can include handling difficulties or even a loss of integrity in the mooring system, and care must be taken to avoid problems for both the chain and any components to which it is connected.

Clearly an understanding of the way in which chains may behave and interact with other mooring components (such as wire rope, which also exhibits coupling between axial load and generated torque) when they are in service is essential. Even with knowledge of the potential problems, there will always be occasions where, despite the utmost care, twist occurs. Thus it is important to be able to determine the effects, but the sizes of chain which are in use in offshore moorings (typical bar diameters are 75 mm and greater) are too large to allow easy testing at meaningful loads and there is virtually no predictive information on the torsional response of chain available in the literature.

This paper addresses the issues and considerations relevant to torque in large mooring chains. The authors introduce a frictionless theory which predicts the torques and end-shortening in the chain as non-dimensionalised functions of the angle of twist. The theoretical model is compared with finite element studies that include friction.

Experimental data is also presented in both “constant twist” and “constant load” forms for stud-less and stud-link chains of 41 and 56 mm bar diameter.

Non-dimensionalised design curves are then given for typical stud-less and stud-link chain geometries, curves which will allow a designer to estimate the torque and end-shortening for any bar diameter, axial load and twist angle combination.

1 Introduction

Chain is widely used in mooring applications for offshore oil platforms, both drilling and production, as well as general marine purposes. It may be used as the sole component in a mooring line, but is more usually employed as part of a system combining chain and rope, be it fibre or wire. There are a number of reasons why chain is a popular choice in a system:

- It is rugged and less damage prone than wire or fibre rope when operating on deck hardware or seabed.
- It is less prone to corrosion than wire rope.
- Chain weight per unit length is higher than for wire rope for a given strength. Hence the chain may be used mid-line as a clump weight to alter the catenary shape, or as a ground line so that a smaller anchor may be employed.
- Chain is intrinsically “torque balanced”, in that an axial load does not generate twist or torsional moments in a straight chain.
- It is easier to handle and requires smaller deck tension equipment than a wire rope.

So why is torsional stiffness, or induced torque, relevant in mooring chain? There are two reasons:

- Firstly, because (as just stated) typical moorings include wire or fibre rope in series with chain, and while chain is intrinsically torque balanced, the other elements may not be, and will try to turn the chain when the combination is subject to axial load.
- Secondly, it is easy to get a mooring twisted during deployment, or during service, often in ways that were not foreseen at the design stage. A means of transferring large amounts of twist into a chain during installation when under nominally zero tension has previously been reported by Chaplin^{1,2}.

It is noted that industry is becoming increasingly aware of the problems which may be caused by allowing components to