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Tensile properties for netting materials used in aquaculture net cages

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Abstract

In order to perform a strength analysis of a net cage, it is crucial to know the tensile stiffness properties of the netting material. A new method for testing was established in order to determine the tensile properties of knotless netting materials. We applied it to a variety of netting materials and developed stress–strain relations. The stiffness was expressed as a constant value for relatively small strains, while for large strains the stress–strain relation was defined by a third degree polynomial. The average value of the constant stiffness for the tested wet netting materials was 81 N mm^{-2} with a standard deviation of 9 N mm^{-2} for strains less than 10%. For netting materials treated with anti-fouling paint, the average constant stiffness value was 131 N mm^{-2} with a standard deviation of 13 N mm^{-2} for strains less than 30%. The results are valid for uniaxial static loading of netting.

Keywords: Aquaculture; Net cages; Nets; Net pens; Netting materials; Material properties; Strength analysis

1. Introduction

Typical fish farms consist of three main components: the net cage, a cage collar and the mooring system (Fig. 1). These different components are equipped with buoyant elements and weights in order to keep the farm floating and to ensure that the net cage maintains its volume.

Net cages are built of a system of ropes and netting (Fig. 1). They are designed to transfer and carry all major forces through the ropes. The netting is attached to the ropes and its intended function is to keep the fish in place. Loads from current, waves and handling induce forces in the netting and it must be dimensioned to withstand this.

The netting used in net cages varies in raw material, size and construction. The netting materials are usually produced of knitted bundles of multifilaments ('knotless' netting) or twines of twisted multifilament bundles that are connected by knots ('knotted' netting). A trade standard exists that defines the number of filaments required to produce netting with a given minimum breaking strength. Most Norwegian net cages are made of square mesh knotless Nylon (Polyamide) netting and Polypropylene/Polyethylene ropes. A variety of other netting materials are available, but knotless Nylon netting is by far the dominating material in aquaculture net cages.

The introduction of the Norwegian standard NS 9415 (Standards Norway, 2003) resulted in legal requirements

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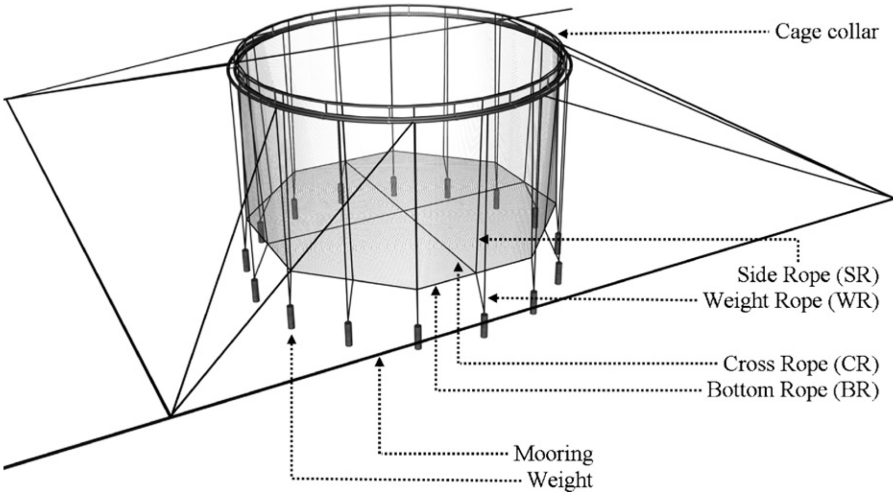

Fig. 1. Illustration of fish farm and net cage components.

for strength analysis of fish farms. Up until then, all net cages had been dimensioned using trade standards based on empirical data. These empirical data were included in NS 9415, but they do not cover all net designs. There is a trend within the Norwegian aquaculture industry that larger net cages and locations with increased exposure to waves and current are used for fish farming (Sunde et al., 2003). The industry has no previous experience with these sizes of nets and environmental conditions, and the new standard requires strength analysis to validate the dimensioning of large net cages and net cages subjected to large environmental loads.

In order to perform a strength analysis of a net cage, it is crucial to know the material properties of the netting material. Traditionally, the material property of major interest for the aquaculture industry has been the tensile breaking strength of netting (mesh) and ropes; comparatively little focus has been on their detailed stiffness properties and general behaviour prior to fracture (Klust, 1982; Sala et al., 2004). There exist established methods for determining the breaking load and elongation of knotted netting materials (knotted twisted yarns), and the netting yarns and knots are tested separately (ISO, 1971; ISO, 2002b; ISO, 1976). Only the mesh breaking force test (ISO, 2002b) is applicable for knotless netting, due to the integrated structure of yarn and knot (Klust, 1982). The resulting stress–strain relation from mesh strength tests does not represent the tensile behaviour of netting materials with loads acting along the twines. Thus, a test new method is needed in order to determine the tensile properties of knotless netting. As a consequence, little information on the stress–strain properties of knotless netting exists. Some information on the mechanical properties for specific dimensions of knotless netting can be found in Slaattelid (1993) and Sala et al. (2004).

Resent research related to aquaculture netting materials focuses mainly on hydrodynamic loading of netting and the resulting response (e.g. Tsukrov et al., 2002; Lader and Fredheim, 2006). Correct material properties will contribute to increasing the accuracy of such analyses.

In this paper, we focus especially on the tensile properties of super-knot Raschel knitted netting. Raschel knitted netting was introduced into the fishing equipment industry in the 1950s. Raschel knitted netting proved to have several qualities superior to the traditionally knotted netting materials, especially due to the lower amount of material in the knot. As a result, Raschel netting is often preferred over knotted netting materials for small mesh widths (Klust, 1982). The mesh widths in netting for traditional Norwegian aquaculture net cages are considered small in this context.

Several different knitting patterns for Raschel netting exist (von Brandt, 1964; Damiani, 1964). The preferred pattern in Norwegian aquaculture netting production is the super-knot pattern, where the knot is strengthened to reduce the risk of laddering of the netting (Fig. 2). Although the netting is called knotless, the connection between twines is still called a knot. The twines are knitted of three strands, each consisting of one to three bundles of very thin filaments (more than 100 filaments in each bundle), as shown in Fig. 2.

The knitted netting has a significant geometric flexibility (Fig. 2); the elongation of the twines and