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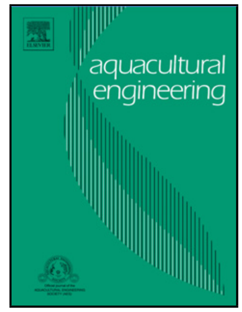

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DRAG FORCES AND DEFORMATION OF AQUACULTURE CAGES – FULL-SCALE TOWING TESTS IN THE FIELD

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ABSTRACT

Fish cages can experience strong loads due to hydrodynamic forces in the sea. Numerical models are often used to estimate drag forces on net cages, and the development and validation of such models is mostly based on laboratory tests that can be performed under controlled conditions. However, several environmental factors are difficult to account for in a laboratory. Experiments using full-scale fish cages in the sea could produce valuable data and new insights on the fluid-structure interaction between sea-cages and ambient flows, given sufficient control over environmental factors. Today very little field data is available on the forces on full scale fish cages in the sea.

In this study, an Atlantic salmon cage (12 m diameter, 6 m depth) was towed in a fjord environment at 5 different speeds to induce a relative water current past the net between 0.1 ms^{-1} and 1 ms^{-1}. Drag on the cage was measured using a load shackle attached to the towing rope and net deformation and cage volume were calculated based on the positions of pressure tags mounted to the net cage.

The towing method produced consistent results on deformation in the range from 0.2 – 1 m/s, and the volume of the net pen decreased almost linearly from 86 % (0.2 ms^{-1}) up to 33% (1.0 ms^{-1}). Measured drag forces and their relationship to flow speed were consistent with existing literature. Drag calculations for net cages generally consider flow speed reduction inside the cage due to blockage effects. However, there are large differences in the flow reduction inside net cages found in few laboratory and field studies, which calls for better descriptions of the flow past net cages. This is illustrated by the comparison of drag calculated by a simple, deterministic model, using a static flow speed reduction of 20% inside the cage and a variable flow speed reduction that depends on the ambient flow speed. The results from this study provide valuable information about the interplay of flow speed, net deformation and drag on a full scale fish cage at different flow speeds and underline the need for a better description of the flow past net cages.

1. INTRODUCTION

Global marine finfish production has almost doubled within the past decade (FAO, 2012) with a total production of about 5.5 million tons in 2012 and continued growth in the future is expected. While some fish farms are located in sheltered areas, for example inside of fjords, an increasing number of production sites is moved towards more exposed areas. Even though other cage concepts have been proposed and are in use, most marine fish farms today use gravity type net cages, which employ weights to retain the shape of a net that is connected to floaters at the water surface.

Currents cause hydrodynamic loads on cages and their moorings (Klebert, et al., 2013), which in turn attenuate and redirect the flow. Water flow in the sea is variable on small and large temporal and spacial scales and gravity cages are flexible and deform under hydrodynamic loads, which leads to complex interactions between cages and currents. A good understanding of these interactions is needed to minimize environmental effects of aquaculture and to ensure the structural safety of fish farm structures as well as good fish health and welfare. The collapse of a complete fish farm during a storm event in Norway in 2005 (Jensen, et al., 2010) highlights that strong hydrodynamic loads on cages and moorings can threaten the structural integrity. The behaviour of and drag on nets in currents and waves have been investigated in a number of studies e.g. (Aarsnes, et al., 1990; Balash, et al., 2009; Gansel, et al., 2014a; Huang, et al., 2006; Lader, et al., 2008; Le Bris, Marichal, 1998; Løland, 1991; Milne, 1972; Moe, et al., 2010; Zhan, et al., 2006) and several authors propose models describing the relationship of flow speed and the drag on nets.

The solidity and shape of nets affects flow patterns past fish cages and the water exchange across nets (e.g.(Bi, et al., 2013; Gansel, et al., 2012; Harendza, et al., 2008), thus defining the transport of dissolved and particulate material through fish cages. Good water exchange rates in fish cages are desired to maximize the oxygen inflow and waste removal. However, on a number of Norwegian salmon farms attempts are made to steer water in an upper layer around cages to prevent the inflow of pathogens across the net (e.g. (Frank, et al., 2014; Stien, et al., 2012)). In the sea, fouling can accumulate on nets at fast rates (e.g. (Bloecher, et al., 2013; Braithwaite, et al., 2007; Yamamoto, et al., 1988), thereby occluding net apertures, which restricts water exchange across nets and increases net drag. Increased drag causes stronger deformation, which may lead to contact between nets and chains holding the sinker tubes of large circular fish cages. This can ultimately cause damages of the net due to chafing. (Jensen, et al., 2010) report structural failure, specifically holes in nets, to be the major cause for escapes from salmon cages in Norway within a three year period from late 2006 on. Strongly deformed

