Ocean Engineering 113 (2016) 34–43

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Review

A new adaptive mesh refinement to model water flow around fishing nets

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ARTICLE INFO

Article history:
Received 13 January 2015
Accepted 7 December 2015
Available online 5 January 2016

Keywords:
Adaptive mesh refinement
Fluid mechanics
3D model
Riemann problem
Fluid structure interaction
Net deployment

ABSTRACT

This paper presents a new adaptive mesh refinement strategy which offers an alternative to the classic AMR methods. The automatic local refinement needs only few additional storage and has good cpu-time results which makes it a fine candidate for some specific studies. It is here applied to a fluid–structure interaction problem: the prediction of the behavior of a submerged net for fisheries applications from fishing companies and scientific questioning. Indeed, the structure code modeling the net already uses a lot of memory space so we introduce a scheme which does not require data structure. The original algorithm employs a local numbering of the cells to identify the neighbor of every cell. The auto-adaptive mesh is applied to the fluid model for a test case describing the hydrodynamic behavior of a netting panel.

Contents

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http://dx.doi.org/10.1016/j.oceaneng.2015.12.009
0029-8018/© 2016 Published by Elsevier Ltd.

1. Introduction

1.1. Context

This work is carried out by the *SOIP project* (Optimization and Innovation System for Fishing) (Le Roux, 2013), supported by the F2DP (Funds of Sustainable Development for the Fishing) which is a trade union created on the initiative of the organs of the Maritime Cooperation (www.cooperationmaritime.com). The main idea of the project is to offer optimized trawl nets to fishing companies using numerical simulations and experimental study.

1.2. Environmental concern

The reduction of energy consumption is one of the most urgent world challenges and the activities of fishing classify among the greediest activities. For illustrative purposes, the consumption of fuel for fishing in France, on the Atlantic Ocean, English Channel and North sea facades, was about 300,000 m^3 in 2009 with 130,000 m^3 dedicated to the trawling, which is near half of the total for the fishing (SIH Ifremer source). Several solutions are in development: optimizations that concern the shape of boats and their resistance against the front waves, the driving machines connected to the propulsion and to the towing. But all these solutions are strongly related to a good estimation of the drag of the trawl net which needs more investigation as the hydrodynamic behavior of the net, made of permeable structures, is still not well-predicted.

1.3. General issue

Trawl structure models that simulate the dynamic behavior of submerged nets are commonly used to help their design and to optimize the setup of the fishing gear. These models are limited by the fact that the sea water is mainly considered as a fluid with uniform velocity and intensity. This work aims to a better understanding of the flow around and across the trawls. The deployment of the trawl is governed by external hydrodynamic forces, which themselves depend on the form taken by the net, so we are facing a real fluid/structure interaction (FSI) problem.

The numerical solution of this problem is based on a coupling between a multidimensional CFD code to predict the velocity fields, and Ifremer's structure 3D code designed to predict the shape of the net. Therefore, to overcome the lack of accuracy of the flow velocity during the modelization of the hydrodynamic behavior of the net, a fluid model was developed which gives a description of the entire flow in terms of velocity and pressure values around the knots of the submerged net structure.

An initial fluid model was developed using a regular Cartesian grid in order to validate the coupling between the two models. However, a regular grid is clearly not adapted to the problem we are dealing with: far from the knots, the velocity of the sea water is not affected by the trawl net. So the mesh used to model the velocities and pressure of the flow should be thin close to the net and coarse far from it. And as the net is moving with the effect of the flow, the mesh should be adapted, increasing the accuracy near the net and being unrefined where the velocity of the water is no more affected by the trawl net. Also, the net is really thin in comparison with its total length, so the modelization deals with very different scales which makes the irregular grid even more appropriate.

The high resolution only in some specific areas of interest can be achieved using the adaptive mesh refinement (AMR). The first structured AMR was developed by Berger and Colella (1989) and improved by many researchers since (Bell et al., 1994; Berger and Colella, 1989; Baeza and Mulet, 2006; Berger and LeVeque, 1998; George and LeVeque, 2006). In these AMR, a hierarchical grid that employs a quad-tree data structure is needed in order to find the neighbors of the cells during the grid adaptation. Clearly, this strategy requires large storage and additional computation work to search the data tree. Some work have been done in order to simplify the data structure (Ji et al., 2010) it would be desirable to have the possibility to apply an AMR with no structure data at all. This work introduces an irregular or unstructured grid which employs a local numbering of the cells using an original algorithm. In this specific case study of a fluid–structure interaction problem, the use of the classic AMR was not possible and the method has revealed itself to be much more efficient than a classic structured regular grid.

1.4. Objectives

The present work aims to offer a new strategy of automatic mesh refinement which has reasonable calculation-time costs and does not require large data structures in order to increase the accuracy of the fluid–structure interaction solution. Indeed, the structure model already employs large space memory and the fish companies need a model which can predict the net behavior in a small amount of time. The use of local numbering to identify the subcells allows infinite level of refinement with very few additional memory storage. First we introduce the 3D CFD model then we present our adaptive mesh refinement strategy. To conclude, the improvement of the fluid model is demonstrated through the study of the hydrodynamic behavior of a netting panel, in which structure data were collected in a test tank at the Ifremer center at Boulogne-sur-mer in 2012.

2. The 3D fluid model

The initial fluid model was developed by Ilyes Mnassri during his thesis: 3D modeling of flows guided by movable permeable walls. Application to problems of Fisheries Technology (Modélisation 3D des écoulements guidés par des parois perméables mobiles. Application aux problèmes de technologies halieutiques), which was presented at Centrale Nantes, 2012 October the 15th and supported by the Hydropeche Project (http://wwz.ifremer.fr/hydropeche_eng, Ifremer, 2012).

The model is based on the resolution of the pseudo-compressible *Navier–Stokes* equations by the finite volume method and based on a explicit time advancement scheme.

2.1. The Navier–Stokes equations

The *Navier–Stokes* equations are used to model the motion of the fluid around the net. They are non-linear and do not admit