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Influence of large hull deformations on the motion response of a fast catamaran craft with varying stiffness

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ABSTRACT

A hydroelastic study of a deformable catamaran is presented. Two-way coupling has been implemented between a RANS (Reynolds Averaged Navier-Stokes) multiphase finite volume flow solver and a finite element method for a highly flexible hull structure. The presented cases consider the hull is advancing at a constant speed in head waves. Different levels of stiffness are tested and deformation time series are recorded. Simulated motion response appears to be very sensitive to the stiffness of the hull which is responsible for a steady and unsteady structural deformation. The deformable hull does not help improve vessel motions. The largest deformations occur at the transom.

The bow and the aft part of the boat acquire a combination of permanent and dynamic deformations. Both of them have the same effect, a variation of the effective length of the boat. As a consequence of the shortening of the hull the pitch restoring moment and the heave resorting force will be reduced. So there will have to be bigger heave and pitch movements to compensate similar forces.

1. Introduction

A small, easy to handle and inexpensive boat capable of exploring and characterizing coastal waters is an essential tool for any laboratory dealing with coastal environmental problems. MIT Sea Grant is such a laboratory and over the years has developed a number of such platforms to carry the necessary instruments and sensors it uses to study the coastal waters of Boston Harbor.

Over the years it has become evident that a catamaran boat is the preferred type of boat because such a boat provides ample deck space to house all the necessary equipment needed to study surface and subsurface (up to 100m) coastal processes. The original Sea Grant catamaran boat was made using rigid hulls (actually canoes). About 5 years ago, ONR (Office of Naval Research) donated to MIT Sea Grant the boat it uses for its coastal research, known as REX (Reef EXplorer, Fig. 1). The catamaran hulls are inflatable, which has proved very convenient for transportation and storage, however, the question arose if the inflatable hulls had an effect on the performance of the vessel. In this paper we answer this question in a qualitative way, setting the basis to study the trade-off between optimum vessel performance and the convenient features of inflatable hulls for daily operation (see Fig. 2).

The study of large deformations in vessels with flexible inflatable hulls has not been widely developed. No particular rigorous scientific evidence exists and at the authors' best knowledge, no studies have been published about hydroelastic behavior of highly flexible hulls. Particularly, no study has attempted to correlate amount of hull deformation with variation in motion response, for a given vessel. This is the main objective of this paper.

Research over the past few years has focused on coupling several of Strip Theory, BEM (Boundary Element Methods) and RANS numerical solvers to a wide range of structural solvers.

In references (Suresh et al., 2016) and (Suresh and Soares, 2016) numerical results are compared with experimental tests obtaining a good agreement. The hydroelastic problem is modeled using a nonlinear time domain method based on Strip Theory, where the hull is modeled as a non-uniform Timoshenko beam. Reference (Enrico, 2004) is another example of linear seakeeping analysis, but with a higher focus on evaluating bending loads on the ship rather than its motion response.

Other linear seakeeping methods have been used successfully in the study of hydro-elasticity such as Rankine panel methods. An example of this can be found in reference (Kazuhiro et al., 2016), which also considers the elastoplastic behavior of the floating structure.

RANS codes have also been used in the study of hydro-elasticity,

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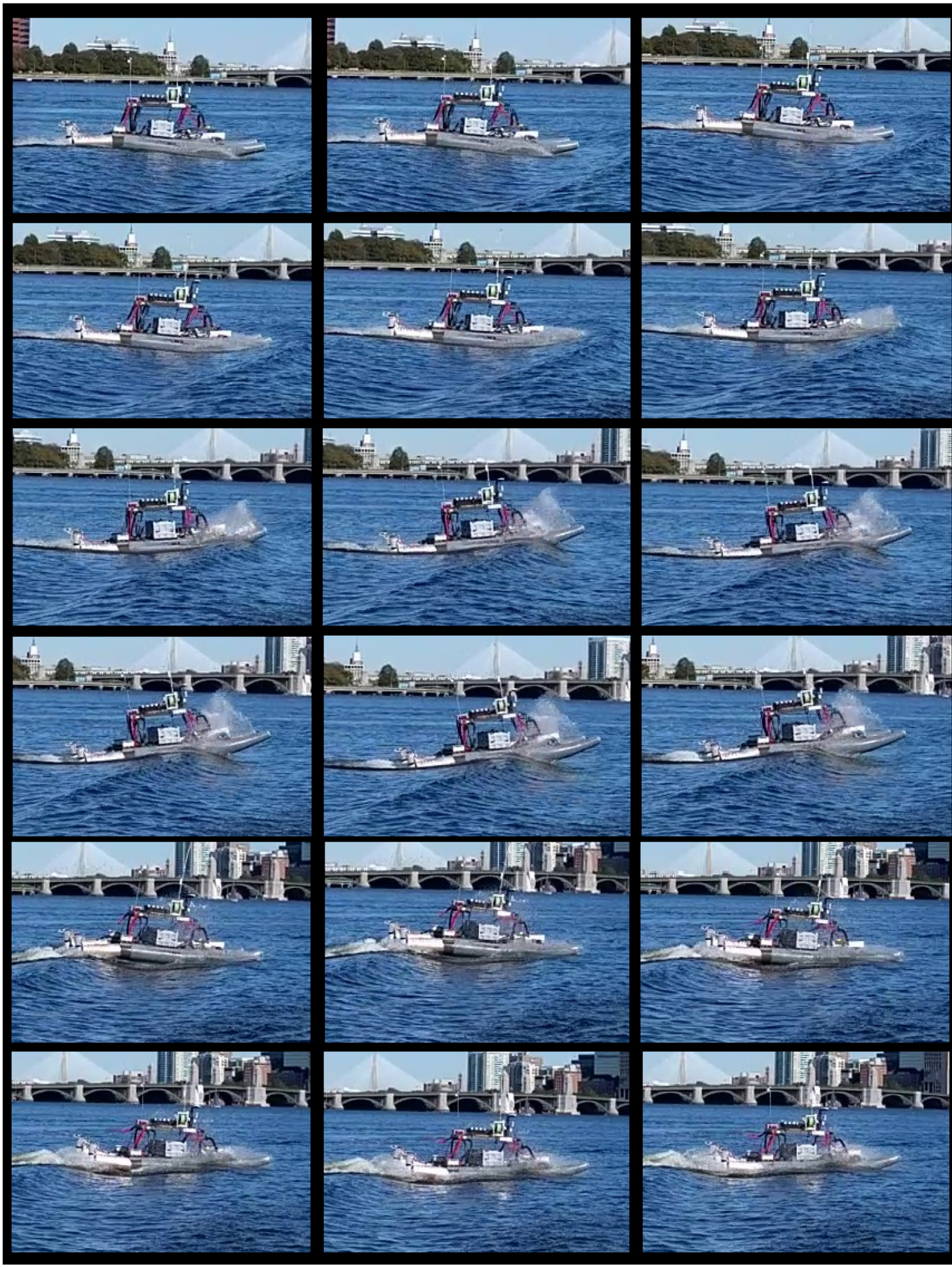

Fig. 1. Time lapse of REX operating in waves.

considering non-linear and viscous effects in the motion response of ships. However, until quite recently, there has not been an extensive validation of RANS codes for motion prediction. In references (Löhrmann et al., 2014) and (Tahsin et al., 2015), a validation of a RANS code for calm water resistance and motion prediction is successfully performed.

An example of a RANS code used to study hydro-elasticity is reference (Lakshmynarayanana et al., 2015), where a two-way coupling is