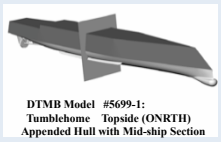
Comparison of Four Dynamic Mesh Techniques for Unsteady Surface Ship Hydrodynamics

Gina Casadei, M.S Candidate, PSU
Eric Paterson, Senior Scientist, ARL

Motivation

- Accurate prediction of transient loads and dynamic response, particularly in high sea states, is of crucial importance when designing ships
- In naval hydrodynamics, there is a need for robust and fast dynamic meshing methods appropriate for analyzing maneuvering and seakeeping of ships
- Want to use CFD methods to develop and validate viscous roll-damping models, since the ones used in seakeeping codes have strictly been empirical in the past
- Use open-source CFD tool OpenFOAM

Geometry



DTMB Model #5699-1: Tumblehome Topside (ONRTH) Appended Hull with Mid-ship Section

$\theta = \theta_1 \sin(\omega t)$

2-D Mid-ship Section of ONRTH with bilge keels

Approach (OpenFOAM)

Free Surface Reynolds Averaged Navier Stokes

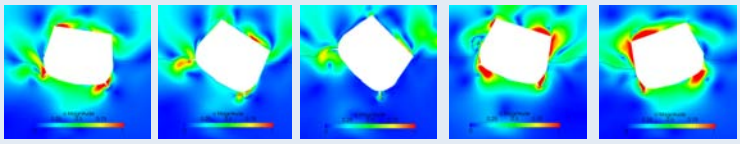
1. Volume of Fluid (VOF) interface capturing
2. Dynamic Mesh Techniques: Laplacian, GGI, RBF, ***Overset***
3. **foamedOver:** using SUGGAR++ and DiRTLib with ***Overset***
4. RANS turbulence modeling
5. Finite Volume Discretization on general polyhedral meshes
6. Parallel computing using domain decomposition and METIS
7. Meshing: Pointwise
8. Visualization: ParaView

Methods

- **Laplacian Mesh Morphing:** entire mesh morphs to ship motions
- **Radial Basis Function (RBF)**: used to prescribe mesh motion, entire mesh morphs to ship motions
- **Generalized Grid Interface (GGI):** communicates via patch interpolation
- **Overset:** reduces single, complex domain into a set of rigid moving meshes which communicate through interpolation

Results

Time History of Tumblehome with Bilge Keels



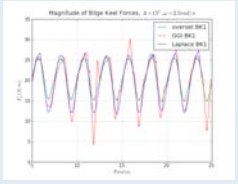
Speed Comparison

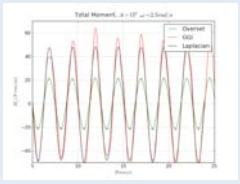
Meshing Techniques	Execution Time for mesh update
GGI	0.06 sec
RBF	40.7 sec
Laplace	2.1 sec
Overset	0.12 sec

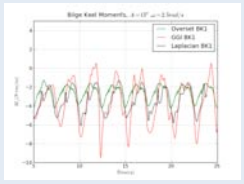
Run Matrix

Fn	0.0
Roll amplitude, deg	15, 30, 45
Roll frequency, rad/s	2.17, 2.5, 2.85, 3.81
Bilge keel configuration	With and without

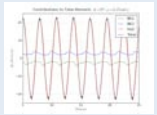
Dynamic Mesh Technique Comparisons



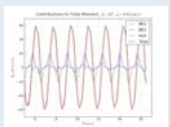




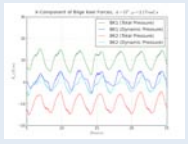
Small Amplitude Roll Motion

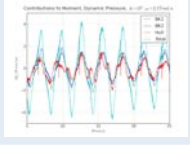


Large Amplitude Roll Motion

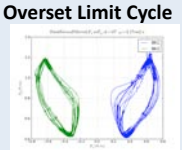


Overset Results





Overset Limit Cycle



Overlap Minimization

Conclusions

Laplace is robust

RBF is very slow, unrealistic for 3-D cases and scales with number of grid points:

2-D - $4N^3$

3-D - $6N^5$

GGI is the fastest method for executing mesh update, but gives noisy results

Overset is the most general for complex geometries and motions For the cases studied, **Bilge Keels** were shown to have small effect on the total roll moment

Prognosis

- Overset is the best option for 3-D, 6 Degrees of Freedom, unsteady, large amplitude, multiphase flow

Future Work

Validation for:

- Resistance
- Dynamic Sinkage and Trim
- Roll Damping with forward speeds
- Other Large Amplitude Motion

Special Thanks To

NAVSEA NAVAL SEA SYSTEMS COMMAND