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8th EMship cycle: October 2017 - February 2019

Master Thesis

Grid Refinement Study of Unstructured Meshes for Marine CFD Cases

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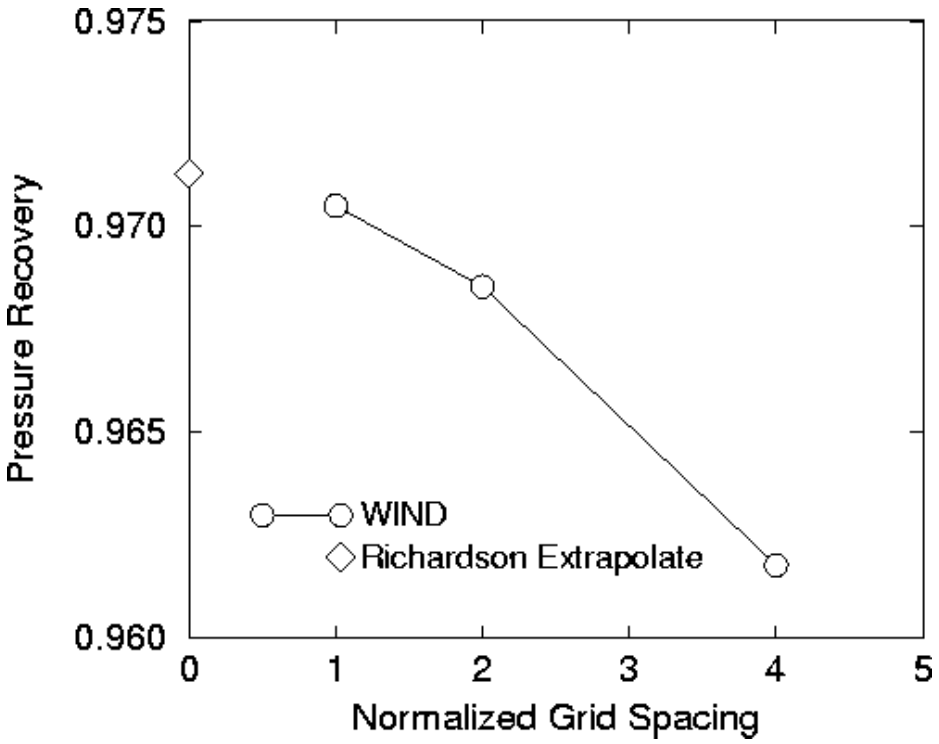
Szczecin, January 2019

1. Introduction

Internship: NUMECA International, Brussels, Belgium

Subject: Grid Convergence (Refinement) Study using FINE/Marine 7.2 package.



Graphic from NPARC Alliance CFD Verification and Validation Web Site

2. Background

general definitions, grid refinement, and guidelines

General Definitions (*AIAA G-077-1998*):

- Uncertainties: *"A **potential** deficiency in any phase or activity of the modelling process that is due to the **lack of knowledge**."*
- Error: *"A recognizable **deficiency** in any phase or activity of modelling and simulation that is not due to lack of knowledge."*

Acknowledged
- Physical approximation error
- Computer round-off error
- Iterative convergence error
- **Discretization error (numerical error)**

Unacknowledged
- Computer programming error
- **Usage error**

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Unacknowledged:
- Computer programming error
- **Usage error**

Minimize spatial error

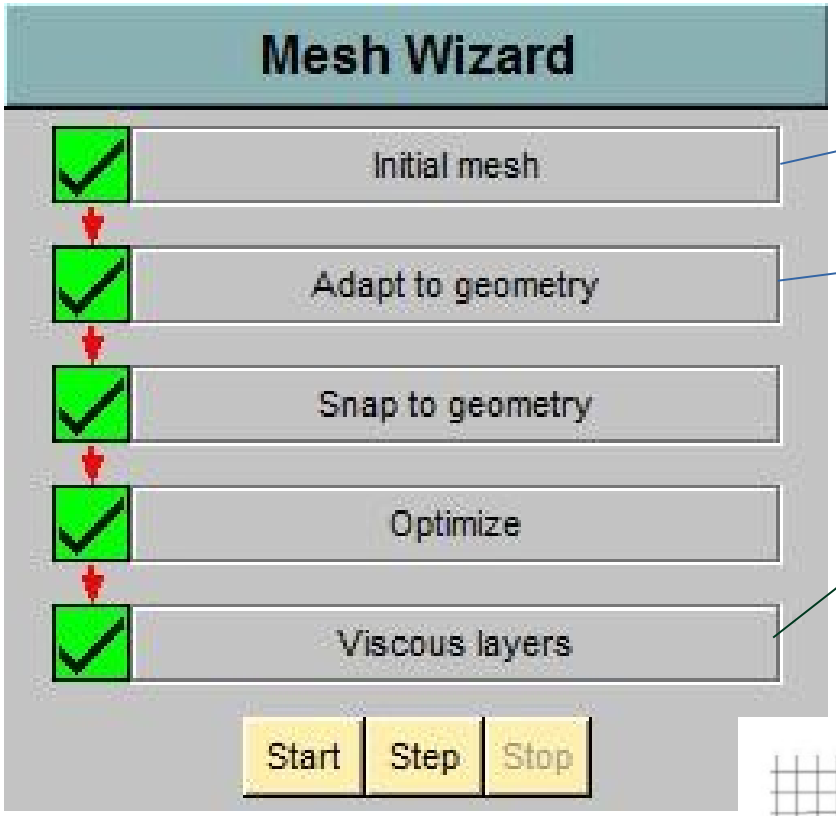
User expertise on grid generator

Grid Refinement Study for Unstructured Meshes

3. Computational Tools

FINE/Marine (Hexpress and ISIS), and
Grid Convergence Study – Data Analysis

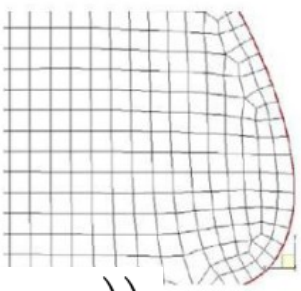
FINE^{tm}/Marine grid unstructured generator - HEXPRESS^{tm}:

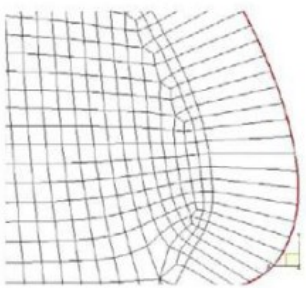


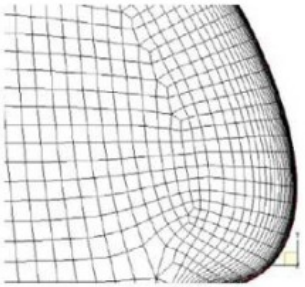
Initial Mesh Division in X, Y, and Z

Target Cell Size Surface and Edge Refinement Ratio Diffusion

Insertion of viscous layer Depends on physical parameters (Reynolds Number)



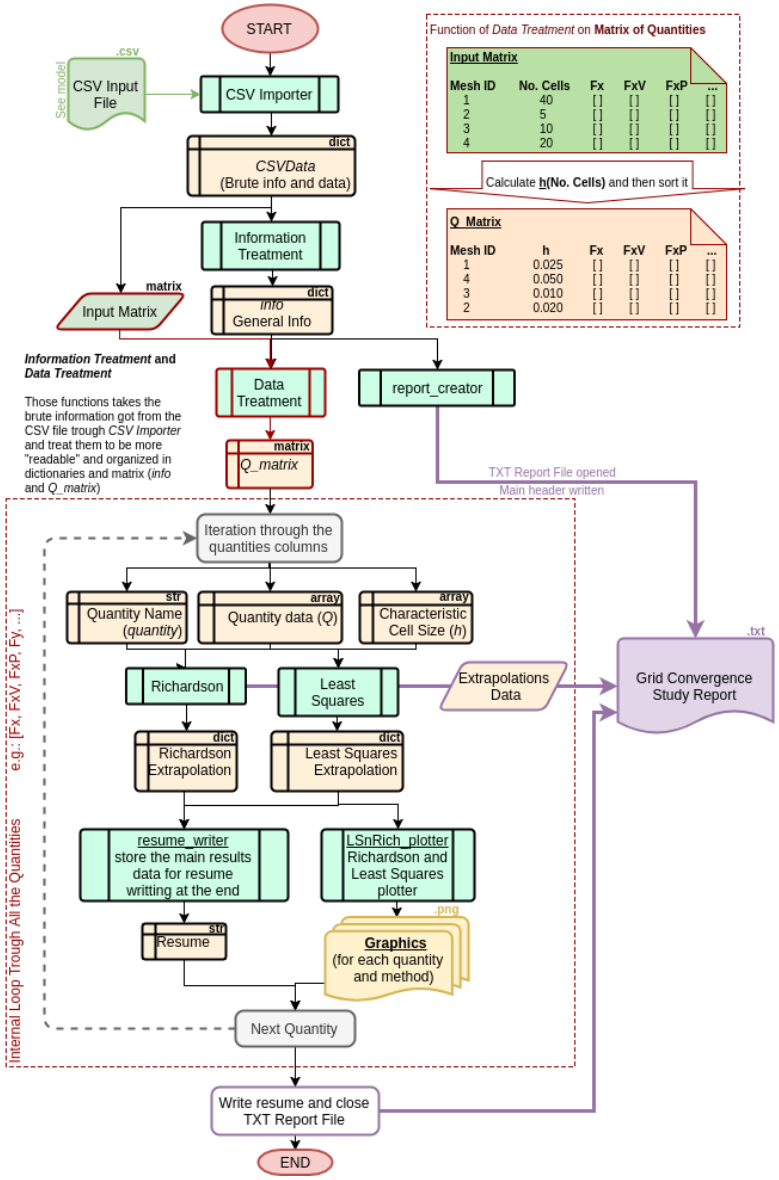




$$y_{wall} = 6\left(\frac{V_{ref}}{\nu}\right)^{-\frac{7}{8}}\left(\frac{L_{ref}}{2}\right)^{\frac{1}{8}} y^{+}$$

$$y^{+} = \max\left(y^{+}_{min}, \min\left(30 + \frac{(Re - 1e^{6}) * 270}{1e^{9}}, y^{+}_{max}\right)\right)$$

Grid Refinement Study – Data Analysis:



4. Methodology

Grid Convergence Study (GCS),
refinement approaches, and
Methods of Evaluation
*(**Richardson extrapolation** & **Least Squares method** extrapolation)*

Refinement Approaches:

- **Approach 1** (constant *Grid Refinement Ratio - r*)
  - Initial mesh parameters
  - Target Cell Sizes
- **Approach 2** (constant *Grid Refinement Ratio - r*)
  - Initial mesh parameters
  - Target Cell Sizes
  - Refinement Diffusion (*D*)
- **Approach 3** (diffusion based *Grid Refinement Ratio - r*)
  - Initial mesh parameters
  - Target Cell Sizes
  - Refinement Diffusion (*D*)

$$\frac{h_{i+1}}{h_i} = \frac{D_i}{D_{i+1}} = r$$

5. Cases of Study

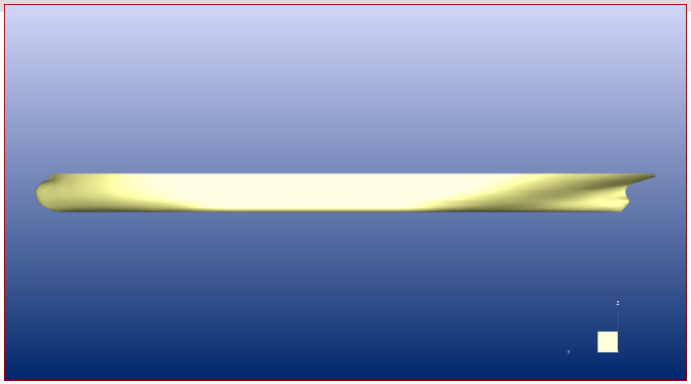
Magnus rotor, KVLCC and DTMB

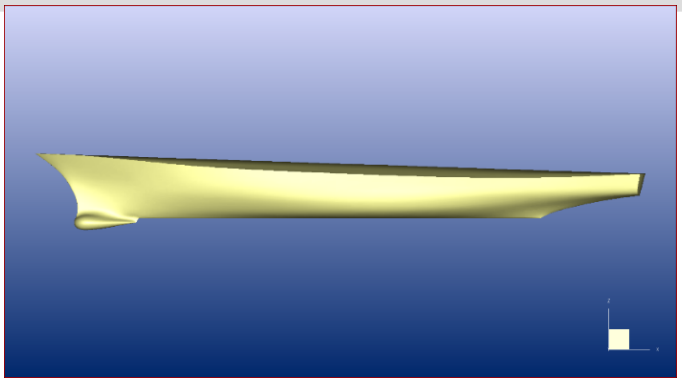
KVLCC (Democase 1):

- Uniform flow of 1.047 m/s;
- Model Length: L = 5.517 m;
- Steady time configuration;
- No body motion
- mono-fluid, turbulence model: k-omega (SST-menter),
- Re: 5.5260E+06,
- wall-function at all solid walls of the vessel.

DTMB (Democase 3):

- Uniform flow of 1.531 m/s;
- Model Length: L = 3.048 m;
- rotation 160 rad/s;
- Steady time configuration;
- Froude Number: Fr = 0.27998
- mono-fluid, turbulence model: k-omega (SST-menter),
- Re: 4.4643E+06,
- wall-function at all solid walls of the vessel, no body motion.
- Quasi-Static: Heave and Pitch



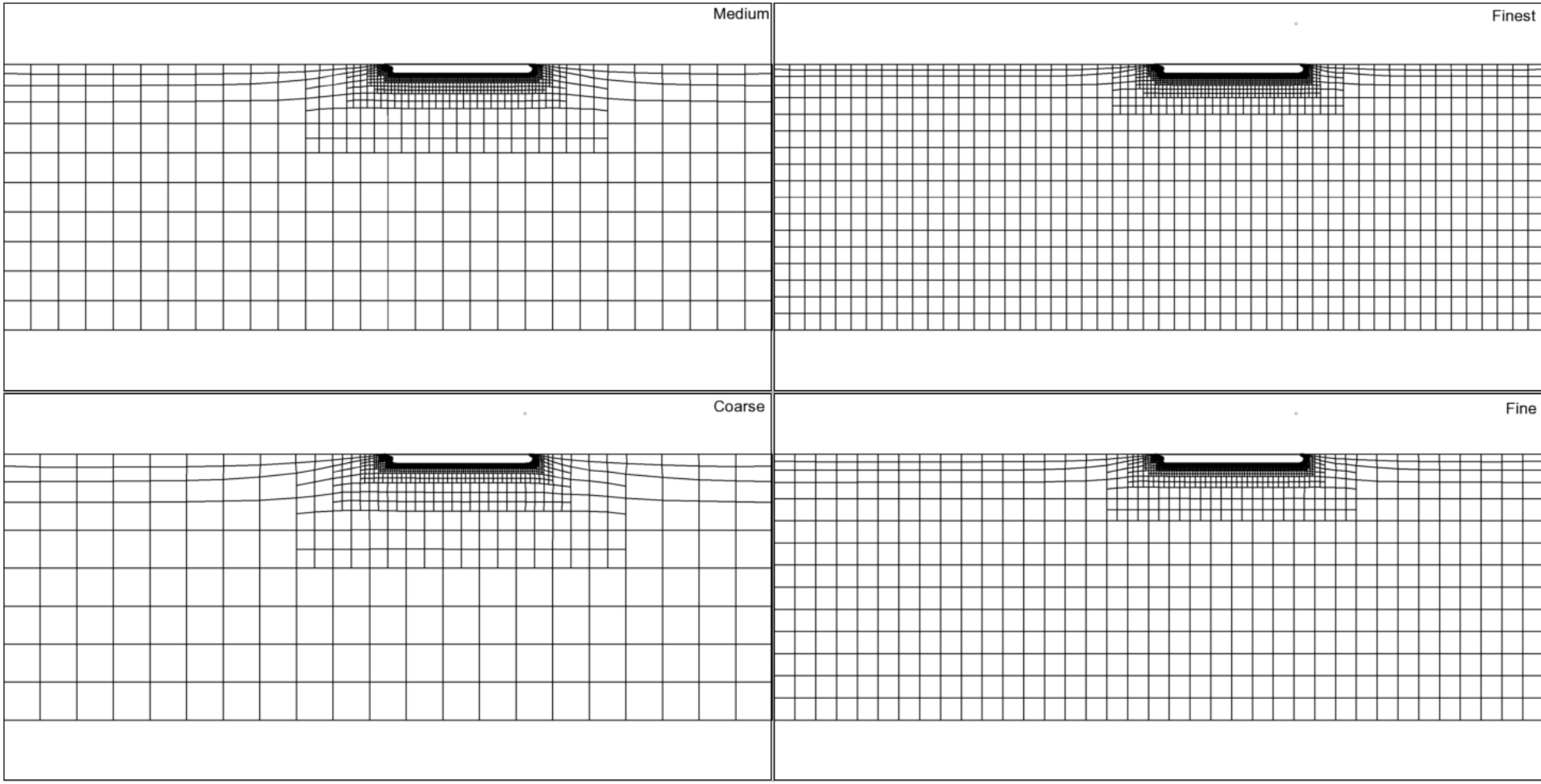


6. Results

Grid Setups, Uncertainties & GCI, order of convergence

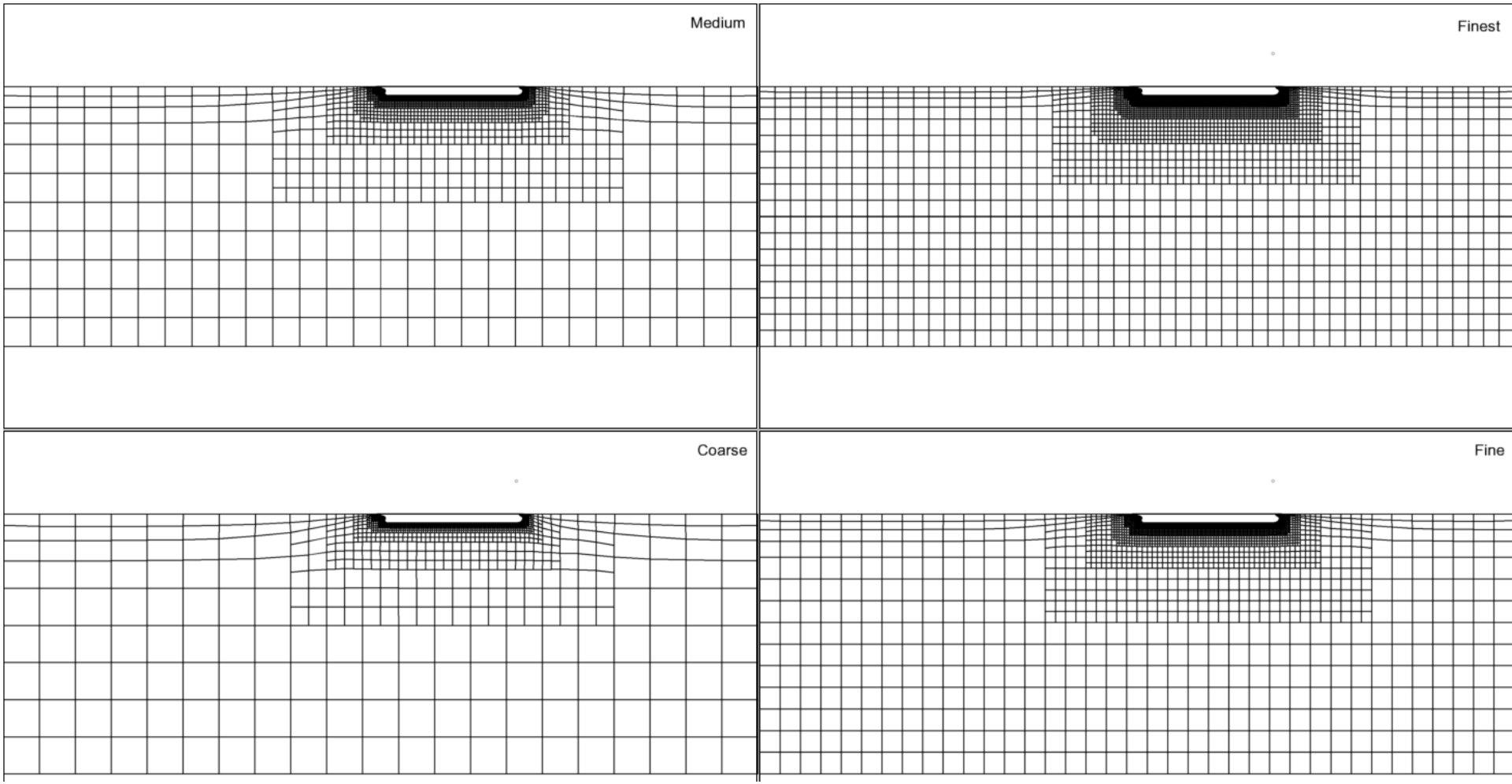
Grid Setup for KVLCC (Democase 1)

Refinement Approach 1



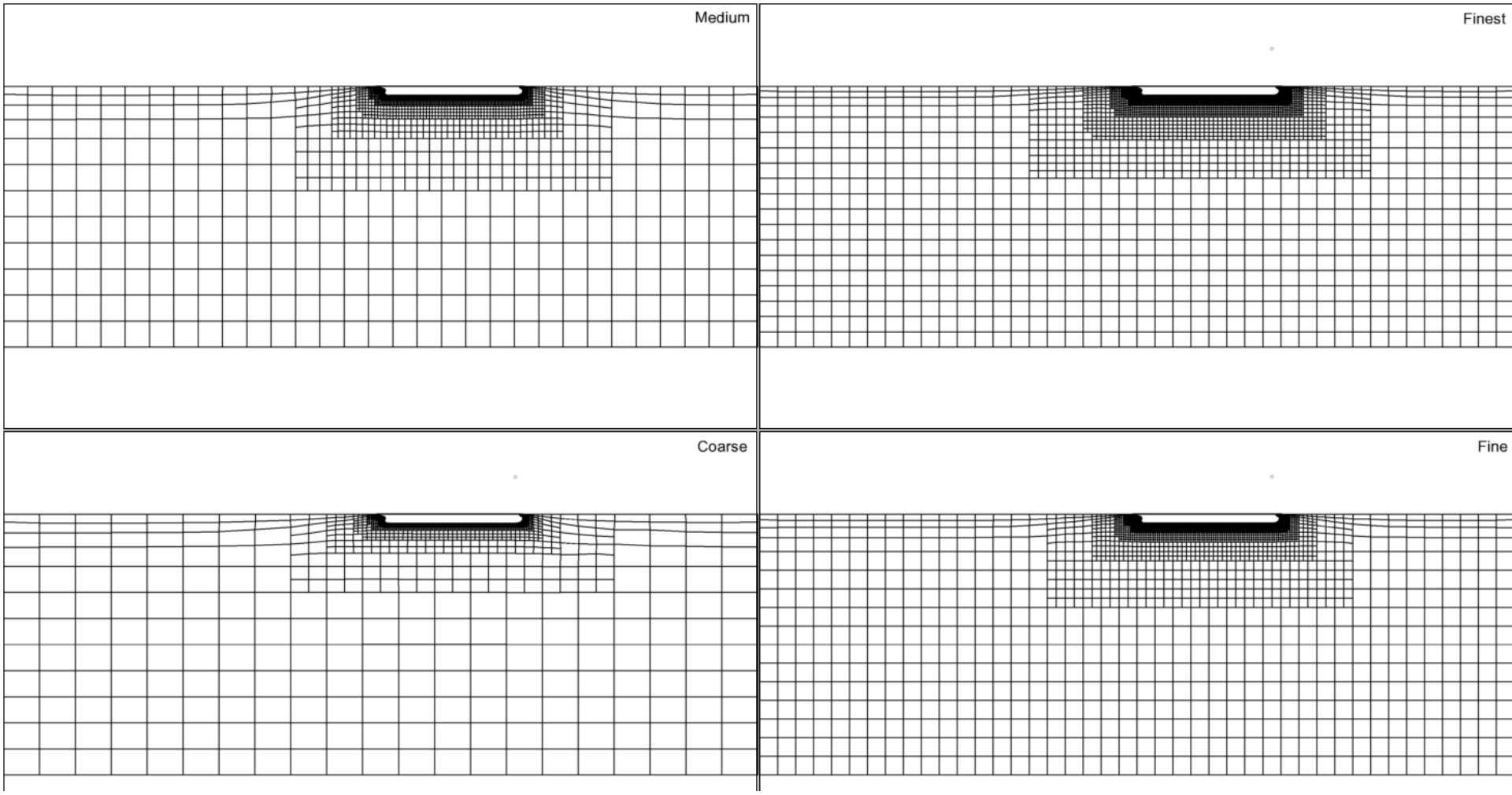
Grid Setup for KVLCC (Democase 1)

Refinement Approach 2



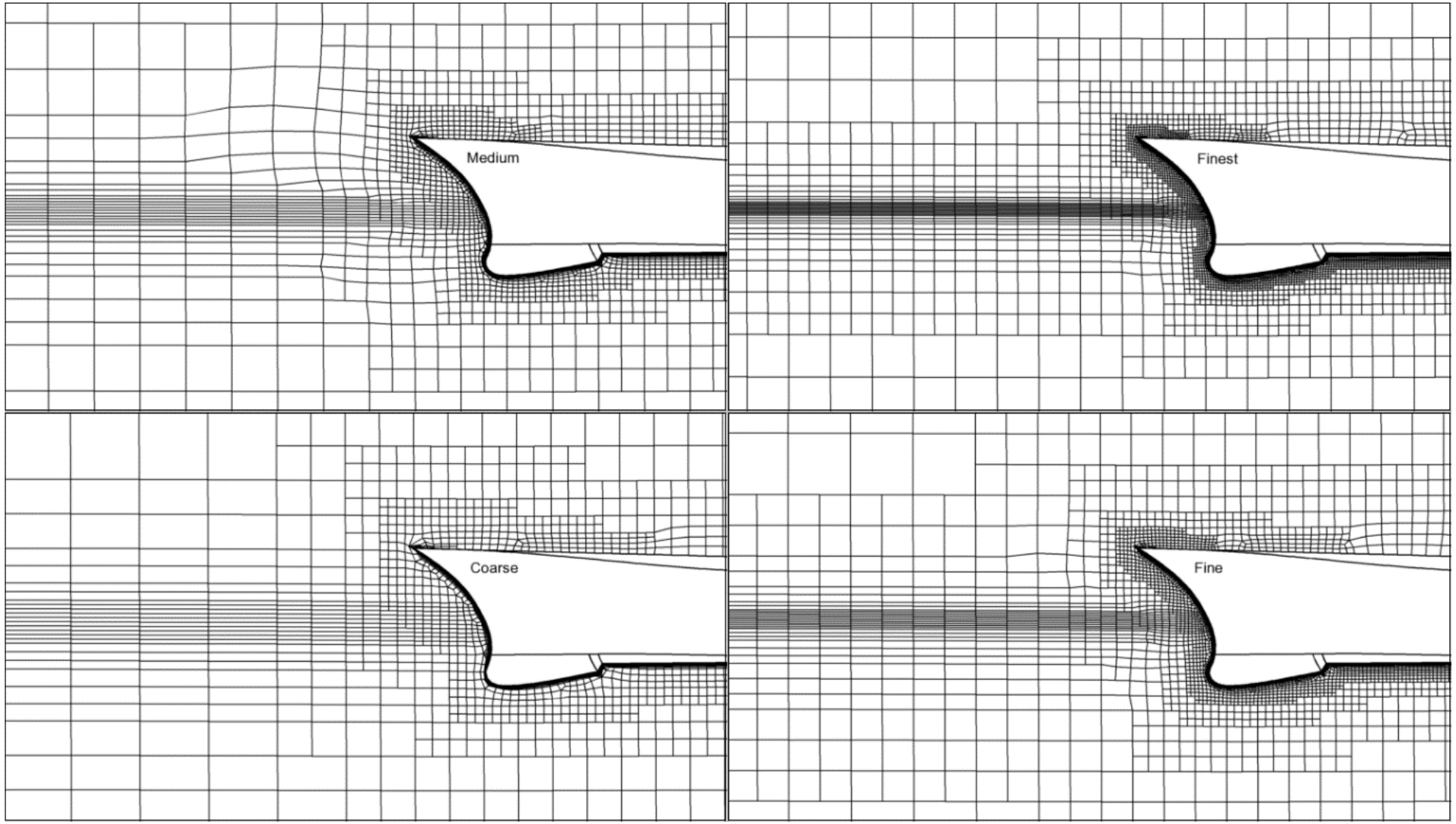
Grid Setup for KVLCC (Democase 1)

Refinement Approach 3



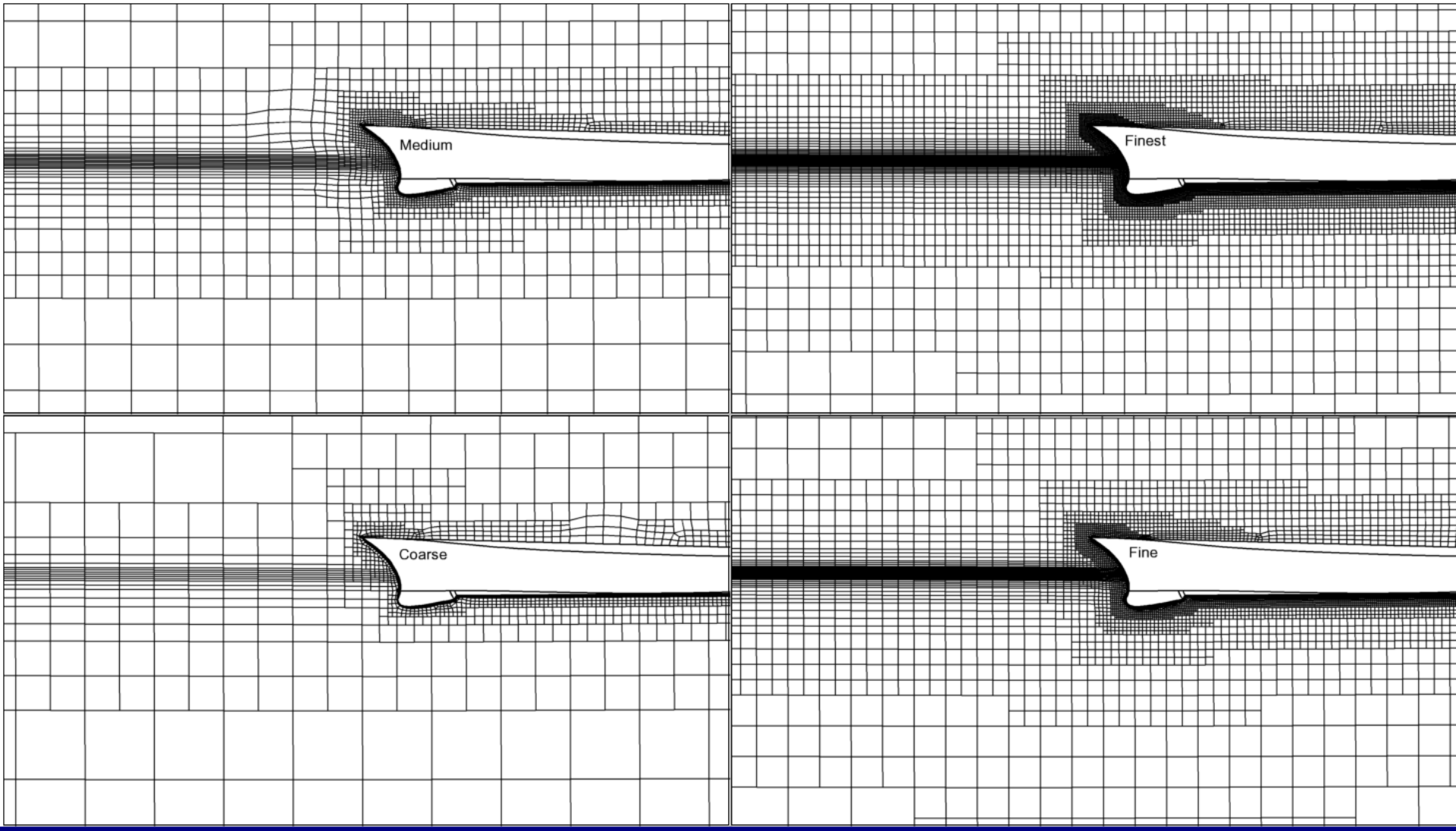
Grid Setup for DTMB (Democase 3)

Refinement Approach 1



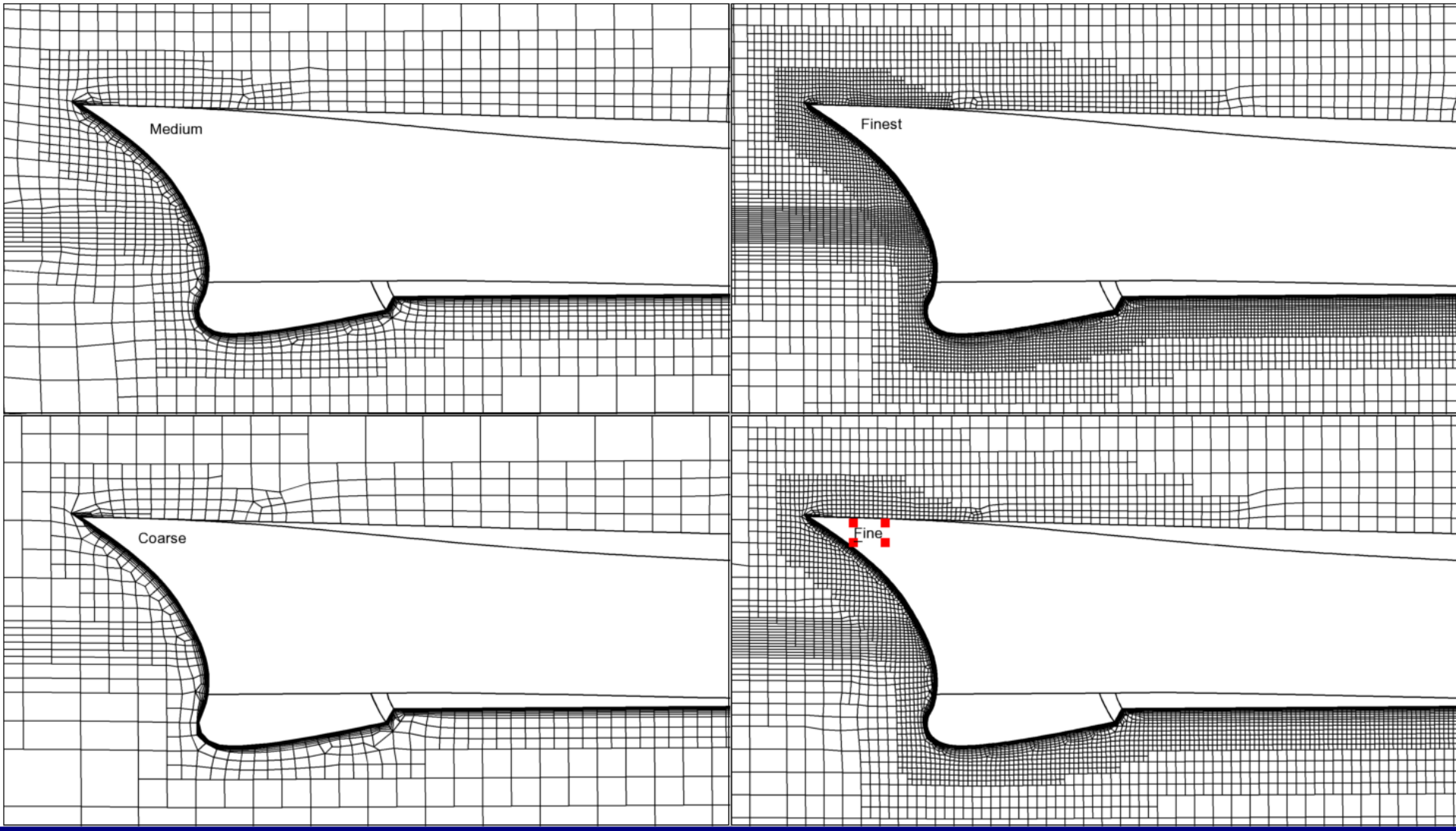
Grid Setup for DTMB (Democase 3)

Refinement Approach 2

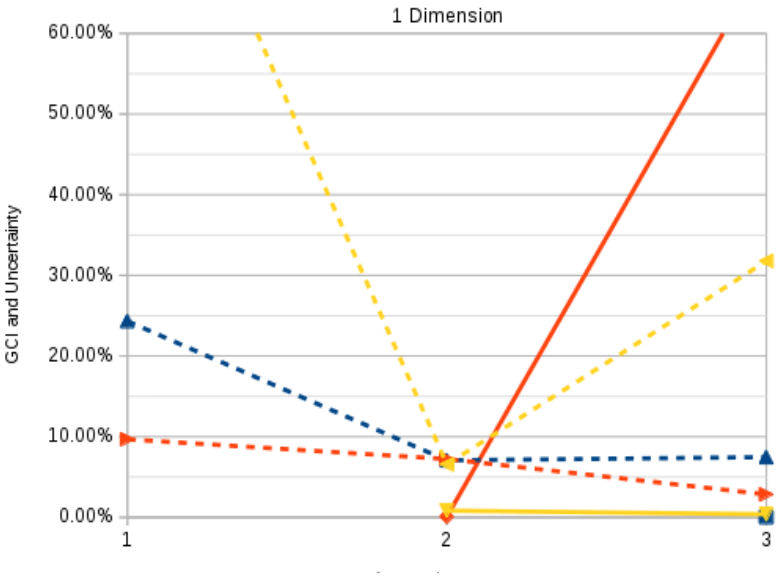


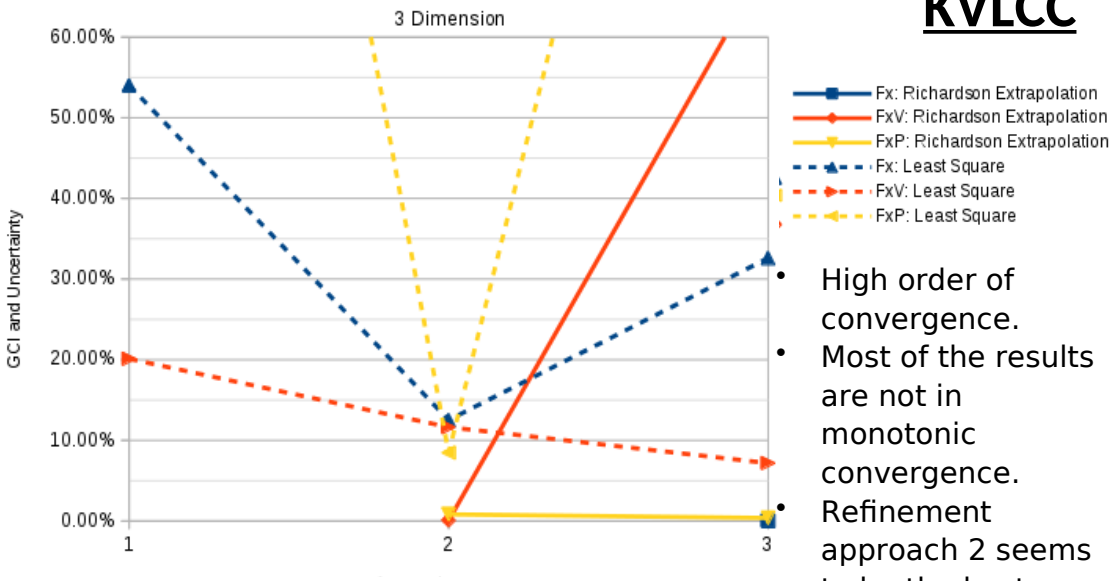
Grid Setup for DTMB (Democase 3)

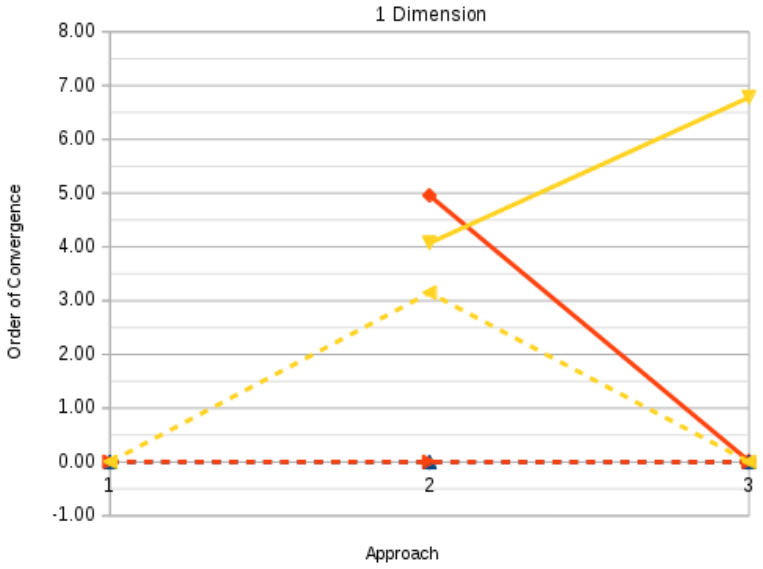
Refinement Approach 3

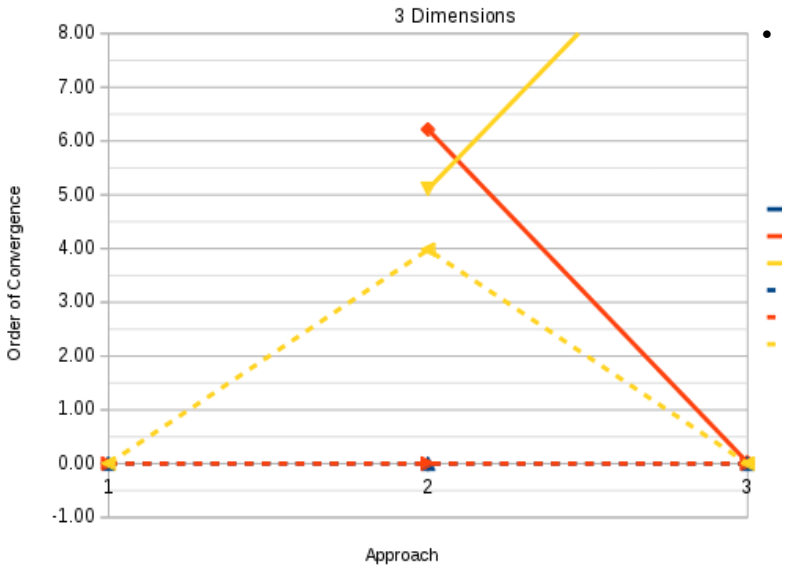


KVLCC

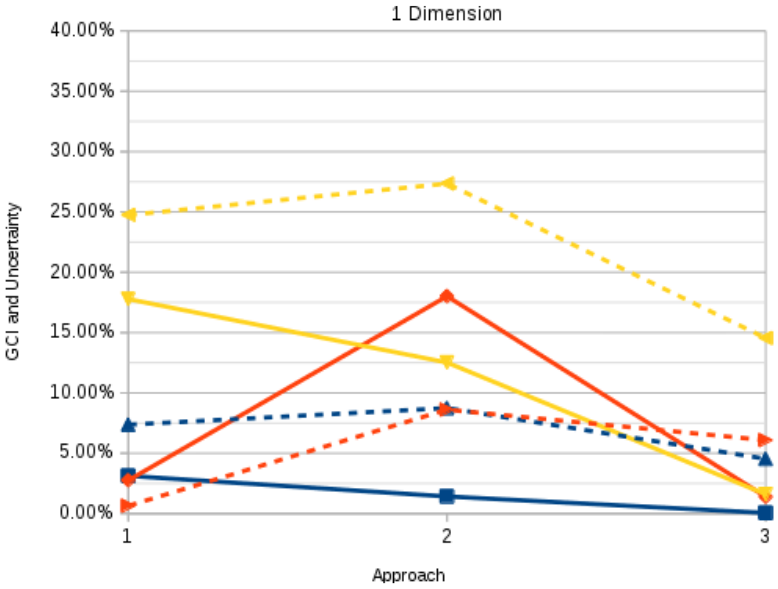


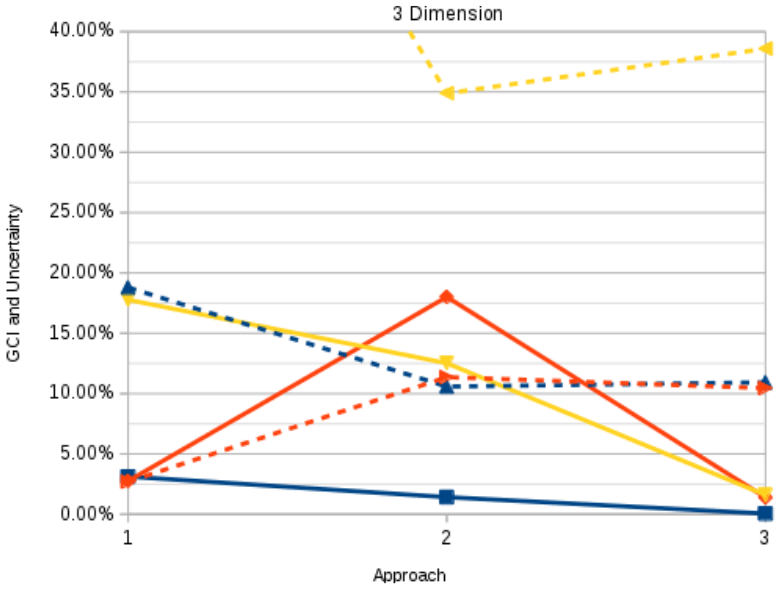


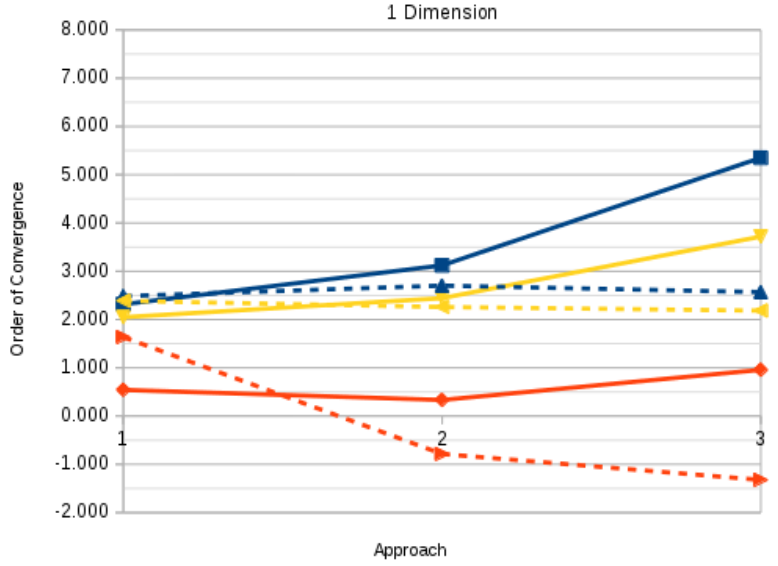


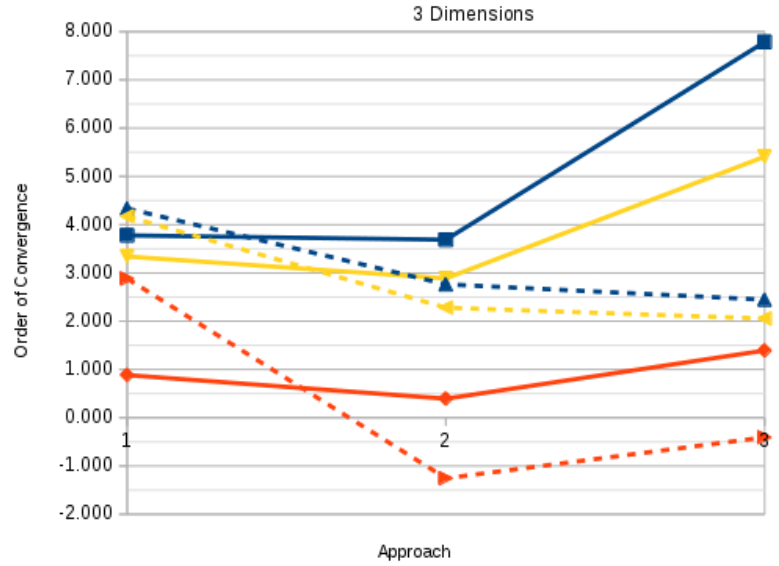


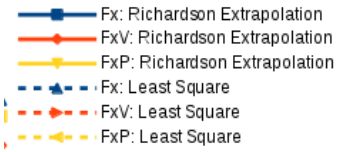
- High order of convergence.
- Most of the results are not in monotonic convergence.
- Refinement approach 2 seems to be the best approach.
- No particular trend to FxV











DTMB

- Order of convergence around 2for FxP and Fx.
- Refinement Approach 3 with 3-D cell size approach have the best order of convergence for LS.
- No particular trend to FxV.

7. Conclusions

Reliable results: DTMB.

- Democase 3 (DTMB) presented with Refinement approach 2 and 3 both 1-D and 3-D approach presented good order of convergence;
- Variable Grid Refinement Ratio can gives good results;
- Diffusion plays a important role on Grid Refinement Study;
- Parameters to be changed for GCS:
  - Diffusion,
  - Initial mesh size,
  - Target cell size on elements,
  - Constant number of refinement.
- Refinement approach 3 have the best grid similitude among the grids.


QUESTIONS

Thank you!

http://www.wildoceanfilm.com/marketing/images/photos/marinelife/Big%20Ship.jpg