

**MEng Project Report**  
**Global Response of Ship Models under the Influence of Surface Waves**

by

Jincong Li

M.Eng, The University of British Columbia, 2024

July 30, 2024

© Jincong Li, 2024

# Contents

<b>1</b>	<b>Abstract</b>	<b>2</b>
<b>2</b>	<b>Introduction</b>	<b>2</b>
<b>3</b>	<b>Methodology</b>	<b>3</b>
3.1	DTMB5415 . . . . .	3
3.2	Mesh . . . . .	5
3.3	Mesh Statistics . . . . .	7
3.4	Wave Configuration . . . . .	7
<b>4</b>	<b>Result</b>	<b>8</b>
<b>5</b>	<b>Discussion</b>	<b>8</b>
<b>6</b>	<b>Future Work</b>	<b>8</b>
<b>7</b>	<b>Conclusion</b>	<b>8</b>
<b>8</b>	<b>Reference</b>	<b>8</b>
<b>9</b>	<b>Appendix</b>	<b>8</b>
9.1	DTMB 5415 Specifications . . . . .	8
9.2	3D Mesh . . . . .	8

# 1 Abstract

## 2 Introduction

This work is a branch of study in Near-Field Noise from Hull and Propeller (HARP). The HARP project focuses on the identification, characterization, and propagation of sound sources, which involve highly nonlinear multiphysics and multiscale physics. This research encompasses both near-field and far-field effects, with a particular emphasis on the following areas:

- **Generation:** Investigation of near-field hull and propeller fluid-structure interaction physics, including bubble wake flows and bubble-wall interactions.
- **Radiation:** Analysis of the far-field effects of the complex dynamical ocean environment, considering factors such as turbulence, waves, currents, temperature, and salinity.

Additionally, the project aims to enhance the physical understanding and mitigation of underwater noise through:

- Evaluating frequency, volume, duration, and the time to reach maximum noise levels.
- Developing monitoring and mitigation techniques, technologies, and methods, such as optimizing ship speed and propeller pitch, and designing bio-inspired propeller blades and hulls.

This comprehensive approach aims to contribute to quieter and more efficient ship designs, balancing environmental performance with operational efficacy.

Underwater radiated noise (URN) sources comes from:

1. vortex created by hull forms and appendages
2. structure vibration creating pressure waves
3. gear mesh
4. propeller crating pressure waves

Thus, as a branch of the HARP project, this work investigated into the global response/vibration of ship models under the influence of surface waves.

### 3 Methodology

The primary workflow of this project involves a two-step process. The initial step is to reproduce the results from Section 9.2 of Vaibhav Joshi's Ph.D. thesis[2]. This section focuses on the analysis of the DTMB5415 ship model. The subsequent step is to replace the DTMB5415 ship model with the BURNSi ship model and conduct a similar model analysis.

The main target of this analysis is to study the heave motion of the BURNSi ship model under the same inlet wave conditions as those described in Section 9.2 of [2]. By maintaining consistent wave conditions, we aim to directly compare the performance and characteristics of the BURNSi ship model against the baseline results obtained from the DTMB5415 ship model.

#### 1. Reproduce Section 9.2 Results:

- Follow the methodology outlined in Vaibhav Joshi's thesis to recreate the results using the DTMB5415 ship model.
- Validate the accuracy and consistency of the reproduced results with the original findings.

#### 2. Model Analysis with BURNSi Ship Model:

- Replace the DTMB5415 ship model with the BURNSi ship model in the simulation framework.
- Conduct a detailed analysis focusing on the heave motion of the BURNSi ship model.
- Utilize the same inlet wave conditions as specified in Section 9.2 of [2] to ensure comparability.

This approach allows for a systematic evaluation of the BURNSi ship model's performance in terms of its heave motion response, providing valuable insights for further improvements and applications.

### 3.1 DTMB5415

The ship model used for the first part of this project is David Taylor Model Basin (DTMB5415), which was conceived as a preliminary design for a Navy surface combatant around 1980. The hull geometry of Model 5415 includes both a sonar dome and a transom stern. Propulsion is provided through twin open-water propellers driven by shafts supported by struts.

It is important to note that no full-scale ship exists for this model. The hull geometry and relevant loading conditions and speeds are detailed in the Appendix section.



Figure 1: DTMB5415

Description		Ship		Model
Scale factor	$\lambda$	-		24.824
Length between perpendiculars	$L_{PP}$ (m)	142.0		5.720
Length at water level	$L_{WL}$ (m)	142.0		5.720
Overall length	$L_{OS}$ (m)			
Breadth	B (m)	18.9		0.76
Draft	T (m)	6.16		0.248
Trim angle	(deg)	0.0		0.0
Displacement	$\Delta$ (t)	8636.0		0.549
Volume	$\nabla$ (m <sup>3</sup> )	8425.4		0.549
Wetted surface	$S_W$ (m <sup>2</sup> )	2949.5		4.786
Hull coefficients				
$L_{PP}/B$	7.530	CB	$\nabla/(L_{PP}BT)$	0.506
$B/T$	3.091	CP	$\nabla/(L_{PP}A_X)$	0.613
$L_E/L_{PP}$	0.550	CPF	$2\nabla_F/(L_{PP}A_X)$	0.594
$L_R/L_{PP}$	0.450	CPA	$2\nabla_A/(L_{PP}A_X)$	0.646
$L_P/L_{PP}$	0.0	CX	$A_X/BT$	0.825
$L_{PP}/\nabla^{1/3}$	6.978	CW	$A_W/(L_{PP}B)$	0.778
$S_W/\nabla^{2/3}$	7.123	CWF	$2A_{WF}/(L_{PP}B)$	0.676
$X_{FB}/L_{PP}$	0.505	CWA	$2A_{WA}/(L_{PP}B)$	0.881

Figure 2: DTMB5415 Specifications

## 3.2 Mesh

Note that for better view, only 2D mesh is presented below. A 3D view is provided in the Appendix section.

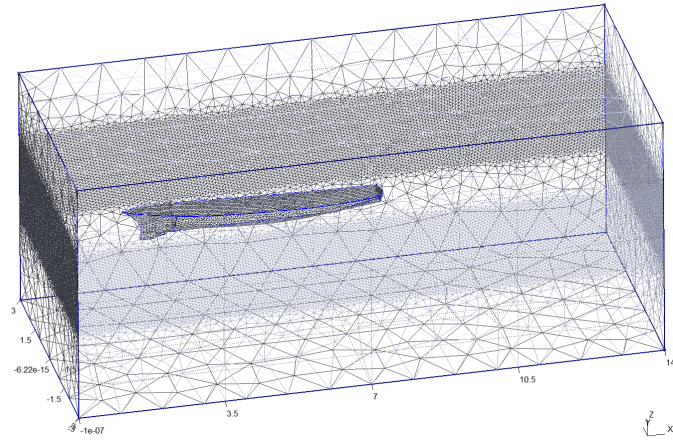


Figure 3: Mesh of the Domain

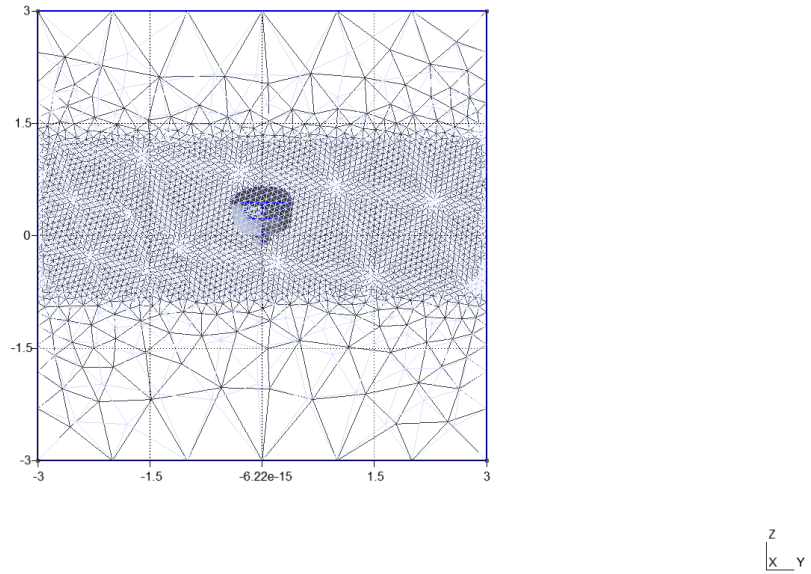


Figure 4: Front View of the Mesh

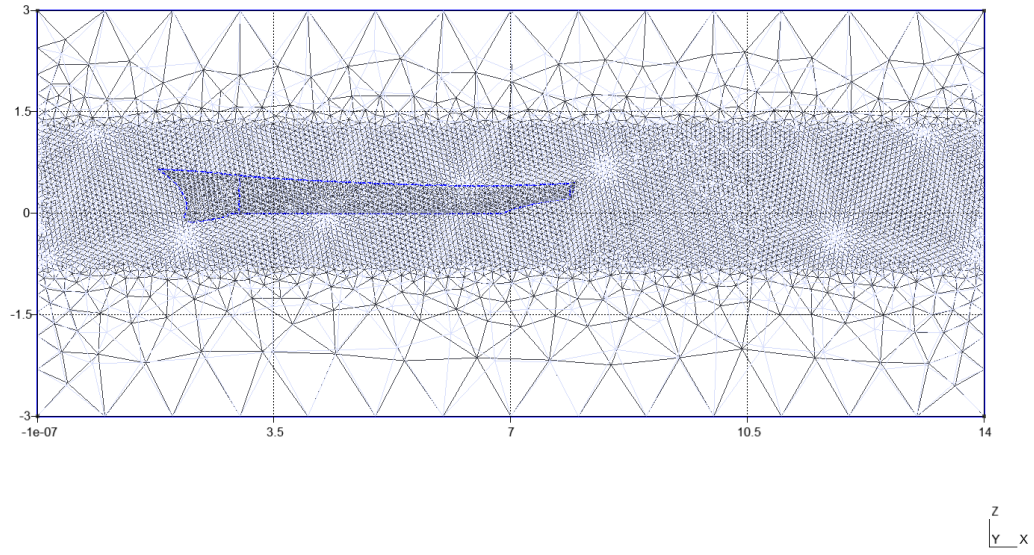


Figure 5: Side View of the Mesh

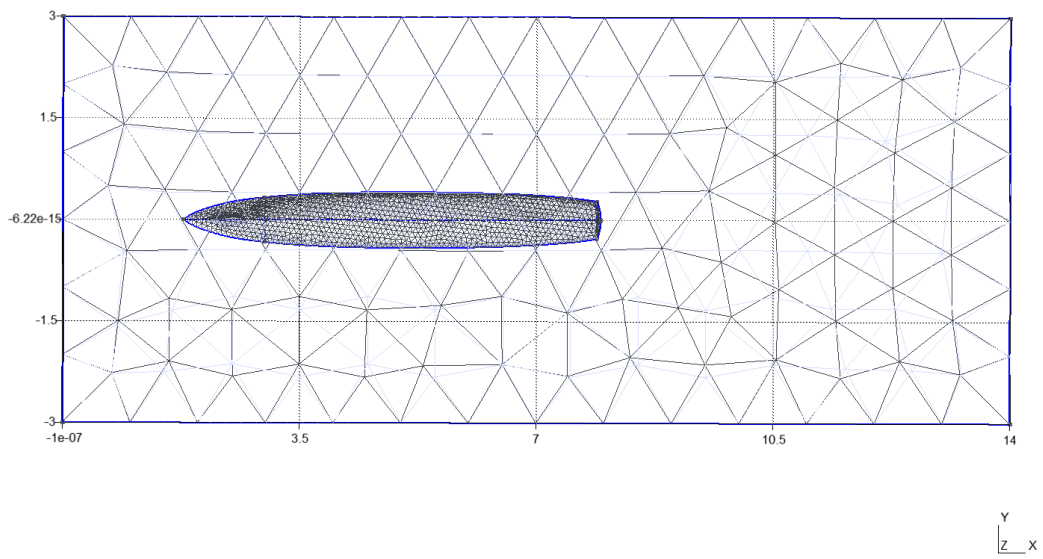


Figure 6: Top View of the Mesh

### 3.3 Mesh Statistics

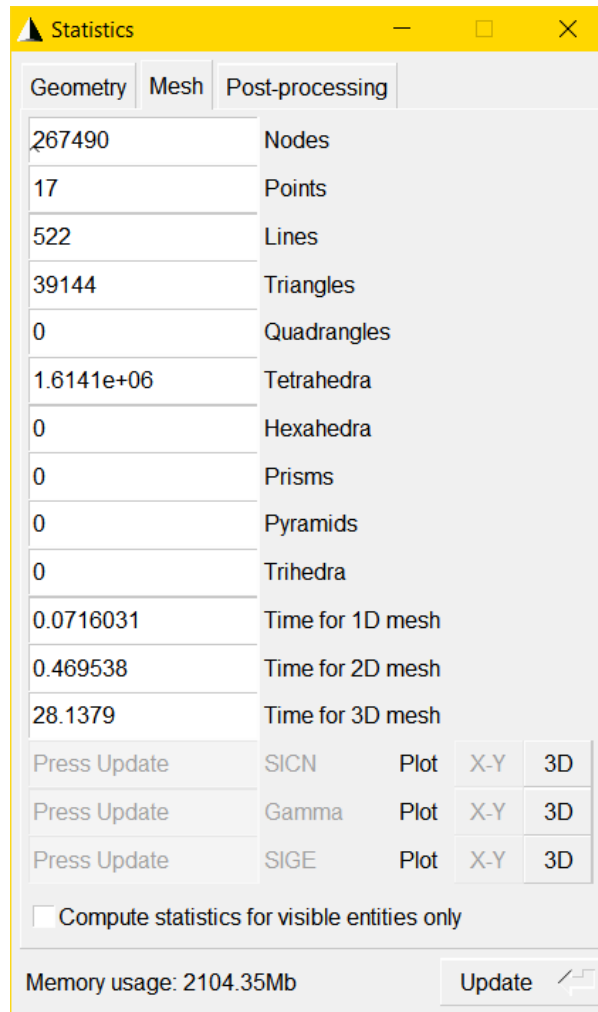


Figure 7: Mesh Statistics

### 3.4 Wave Configuration

Table 1: Wave Conditions

Parameters	Value	Unit
$H_w$	0.32032	m
$k_w$	1.0845	m
$\lambda_w$	0.91	m
$T_w$	1.929	m



## 4 Result

## 5 Discussion

As a section of the HARP project, this work facilitates developing innovative tools for predicting underwater vessel noise during the design phase. It will identify potential noise sources, such as on-board machinery and propeller noise. Enhanced design models are anticipated to assist the industry in adopting ‘quiet’ technologies for the next generation of ships, ensuring they maintain safety, productivity, and environmental performance.

## 6 Future Work

This work has only completed the first step of the scope stated in the methodology section. The future work is to replace the DTMB ship model with BURNSi model and conduct test using the set-up mentioned above.

## 7 Conclusion

## 8 Reference

### References

- [1] A. Kendrick and R. Terweij, *Ship Underwater Radiated Noise*, Report 368-000-01, Rev 5, Vard Marine Inc., 08 July 2019.
- [2] Vaibhav Joshi, *Variational Methods and Applications for Turbulent Single and Two-Phase Fluid-Structure Interaction*, ScholarBank@NUS Repository, 2018.
- [3] A. Olivieri, F. Pistani, A. Avanzini, F. Stern, and R. Penna, *Towing tank experiments of resistance, sinkage and trim, boundary layer, wake, and free surface flow around a naval combatant INSEAN 2340 model*, IIHR Technical Report No. 421, 2001.

## 9 Appendix

### 9.1 DTMB 5415 Specifications

### 9.2 3D Mesh

	<b>Full-Scale</b>	<b>MARIN</b>	<b>INSEAN</b>	<b>IIHR</b>	
<b>Lpp (m)</b>	142.00	4.002	4.002	5.719	3.048
<b>Lwl (m)</b>	142.18	4.007	4.008	5.726	3.052
<b>Bwl (m)</b>	19.06	0.537	0.538	0.768	0.409
<b>T (m)</b>	6.15	0.173	0.172	0.248	0.132
<b>Displacement (m<sup>3</sup>)</b>	8424.4	0.189	0.188	0.554	0.0826
<b>S w/o rudder (m<sup>2</sup>)</b>	2972.6	2.361	2.424	TBD	TBD
<b>CB</b>	0.507	0.507	0.507	0.506	TBD
<b>CM</b>	0.821	0.821	0.821	0.821	0.821
<b>LCB (%Lpp), fwd+</b>	-0.683	-0.683	-0.652	-0.652	TBD

Table 2: Main particulars of the ship model

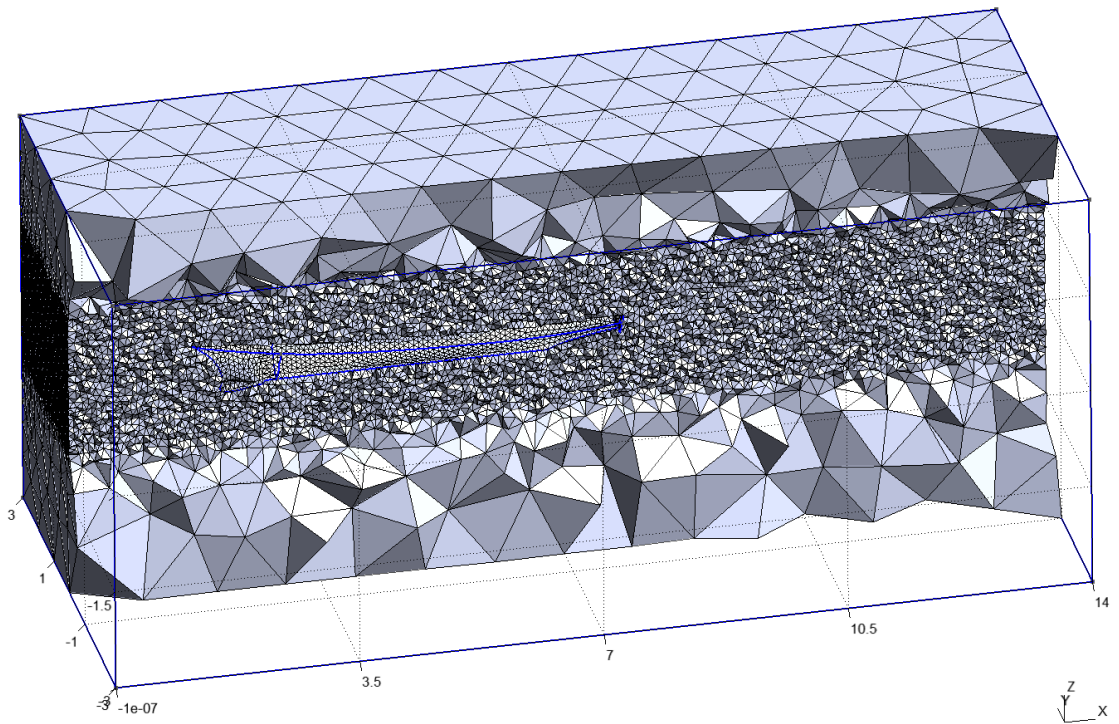


Figure 8: 3D Mesh