



**ALGORITHMIC MODIFICATIONS TO A  
MULTIDISCIPLINARY DESIGN OPTIMIZATION  
MODEL OF CONTAINERSHIPS**

By

**Sandipan Ganguly**

Thesis submitted to the Faculty of Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE  
In  
OCEAN ENGINEERING

Committee members:

Dr Wayne Neu, Chairman  
Dr William H Mason  
Dr Alan Brown

Date of defence: 05/06/2002, Blacksburg, VA.

# ALGORITHMIC MODIFICATIONS TO A MULTIDISCIPLINARY DESIGN OPTIMIZATION MODEL OF CONTAINERSHIPS

Sandipan Ganguly

## Abstract

When designing a ship, a designer often begins with “an idea” of what the ship might look like and what specifications the ship should meet. The multidisciplinary design optimization model is a tool that combines an analysis and an optimization process and uses a measure of merit to obtain what it infers to be the best design. All that the designer has to know is the range of values of certain design variables that confine the design within a lower and an upper bound. The designer then feeds the MDO model with any arbitrary design within the bounds and the model searches for the best design that minimizes or maximizes a measure of merit and also meets a set of structural and stability requirements.

The model is multidisciplinary because the analysis process, which calculates the measure of merit and other performance parameters, can be a combination of sub-processes used in various fields of engineering. The optimization process can also be a variety of mathematical programming techniques depending on the type of the design problem. The container ship design problem is a combination of discrete and continuous sub-problems. But to avail the advantages of gradient-based optimization algorithms, the design problem is molded into a fully continuous problem.

The efficiency and effectiveness with which an optimization process achieves the best design depends on how well the design problem is posed for the optimizer and how well that particular optimization algorithm tackles the type of design problems posed before it. This led the author to investigate the details of the analysis and the optimization process within the MDO model and make modifications to each of the processes, so that the two become more compatible towards achieving a better final design. Modifications made within the optimization algorithm were then used to develop a generalized modification method that can be used to improve any gradient-based optimization algorithm.

# Acknowledgements

I am grateful to a number of people who have helped me in understanding and undertaking research in the field of Multidisciplinary Design Optimization.

I would like to thank Dr Wayne Neu, my advisor for his relentless support and guidance. I would also like to thank my committee members, Dr Alan Brown and Dr William Mason for their help and continuous encouragement.

I would also like to thank the graduate students of the Marine MDO project who have helped me to merge smoothly into the mainstream research in the project.

Thanks are also due to the staffs of the AOE department who make things so much easier.

# Table of Contents

Acknowledgements	(i)
Abstract	(ii)
List of Tables	(v)
List of Figures	(vi)
List of Symbols	(vii)
Chapter1: Introduction	1
Chapter 2: Organization and Formulation	5
2.1 Project Organization	5
2.2 Problem Formulation	9
2.3 Scaling and Normalizing	12
Chapter 3: The Problem of Adding Ballast	13
3.1 Statement of the Problem	13
3.2 Exploration of the Optimization Algorithm	15
3.3 SLP with DOT	18
Chapter 4: Causes of the Ballast Problem	31
4.1 Hypersensitivity of the GM constraint	32
4.2 Competing Constraints	35
Chapter 5: Solution to the Ballast Problem	36
5.1 Scaling the GM constraint	36
5.2 Modification of the Search Direction	38
Chapter 6: Modification of the Search Direction and its general applicability	43
6.1 Deriving the modification	43
6.2 Implementation in the MDO model	46
6.3 Implementation in general design optimization problems	47
6.4 General formulation of Search Modification	49
Chapter 7: Changes to the analysis process	51
7.1 A new constraint	50
7.2 New weight formulation	52
Chapter 8: Software Overview	54

Chapter 9: Conclusion	57
References	58
Appendix	59

# List of Tables

<b>Table</b>	<b>Description</b>	<b>Page</b>
2.1	The design variables	10
3.1	Case 1: Starting with zero ballast	14
3.2	Case 2: Starting with non-zero ballast (Ballast=2)	14
3.3	Case 3: Starting with non-zero ballast (Ballast=12)	15
4.1	Sensitivity of the constraints	32
4.2	Gradients of the objective function and minimum GM constraint	33
5.1	Comparison of results between scaled and un-scaled constraints	36
5.2	Comparison of final results for differing values of Ballast.	38
6.1	Comparison of final result	43
7.1	The effect of adding $L/D_{\max}$ constraint	49
7.2	Estimating the goodness of fit for the new weight formula	50
8.1	Interfaces in the Input module	52
8.2	Methods and properties in the interface IVTInputfile	52
8.3	Properties exposed in the IVTShip Parameter Interface	53

# List of Figures

Figure	Description	Page
1.1	Interaction	2
2.1	Process flow within the MDO project	5
3.1	Before Linearization	16
3.2	After First Linearization	16
3.3	After Second Linearization	17
3.4	Last Iteration	17
3.5	SLP with DOT	19
3.6	Search Direction in the active region	22
3.7	Search Direction in the violated region	23
3.8	One-dimensional minimization	28,29
4.1	Iteration history of constraint values	33
4.2	A two-dimensional analogy	35
5.1	Constraint values for the last few iterations	38
6.1	Two – dimensional example	39
6.2	Modification of the search direction	41
6.3	Modified search direction	42
6.4	Iteration history comparing the two algorithms	44
6.5	How MMFD performs in competing constraints	45
6.6	How modification of search direction helps overcome competing constraints	46
7.1	Curve fitting for weight formula.	50
8.1	A representation of COM object with interfaces	51

# List of Symbols and Abbreviations

Symbols and Abbreviations	Description	Units
$\alpha$	Variable for 1-D Minimization	
B/D	Beam/Depth	
C1	Blending Coefficient	
CG	Height of the center of gravity from keel	Meters
COM	Component Object Model	
CT	Maximum constraint value for being active	
CTMIN	Maximum constraint value for being violated	
DOT	Design Optimization Tools	
F(X)	Objective Function	\$/ton/k-mile
FB	Freeboard	Meters
FB <sub>min</sub>	Minimum Freeboard	Meters
g(X)	Inequality Constraint	
GM	Metacentric height	Meters
GM <sub>min</sub>	Minimum metacentric height	Meters
$\nabla F$	Gradient of Objective Function	
$\nabla g$	Gradient of inequality constraint	
$\nabla h$	Gradient of equality constraint	
h(X)	Equality constraint	
IBar	Interface Bar	
IFoo	Interface Foo	
L/D	Length/Depth	
L/D <sub>max</sub>	Maximum length/depth	
$\lambda$	Weight parameter	
MDO	Multidisciplinary Design Optimization	
MMFD	Modified Method of Feasible Directions	
N	Net Point	
NT <sub>d</sub>	Number of tiers on deck	
$\phi$	Positive Integer	
RFR	Required Freight Rate	\$/ton/k-mile
RFR <sub>i</sub>	Initial required freight rate	\$/ton/k-mile
RMS	Root Mean Square	
S <sup>q</sup>	Search Vector in the q <sup>th</sup> iteration	
SLP	Sequential Linear Programming	
TEU	Twenty-foot Equivalent Unit	
$\theta$	Push-off factor	
W	Artificial Variable	
X <sup>q</sup>	Vector of design variables in the q <sup>th</sup> iteration	