NUMERICAL STUDY ON SHIP MOTION WITH LNG TANK SLOSHING

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering

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DECLARATION

I declare that this project report entitled “Numerical Study on Ship Motion with LNG Tank Sloshing” is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:.	....
Supervisor's Name	:	....
Date	:	....

DEDICATION

To my supervisor Dr. Mohamad Shukri bin Zakaria, PhD,

My late father Hasbullah bin Ramli,

My lovely mother Masitah binti Hanapiah,

My fellow friends,

Brother and Sisters,

Thank you for everything.

ABSTRACT

Ship motions excites the LNG tank sloshing in ship cargo when there is a violent sea waves, which causes impact load on tank wall and then influences the ship movement. Focusing on the Open Field Operation and Manipulation (OpenFOAM) development platform of the open source Computational Fluid Dynamics (CFD), numerical calculation of ship motion with tank sloshing is attained and the correlating numerical simulation and verification is performed. For this process, the waves and tank sloshing interactions are fully taken into account. The liquid sloshing motion in membrane tank is firstly simulate through six degrees of freedom motion. Liquid filling levels are set as 25%, 50%, 75% and 90% of the tank's volume, respectively, in order to find the highest maximum pressure. Then, the simulation is further conducted using baffles in order to control the maximum impact pressure in membrane tank. The key findings are: the impact pressure for 75% filling level of LNG is highest comparing to the other filling levels. The maximum impact of pressure for combinatorial baffles greatly reduced by 28% comparing with the tank with no baffle case.

ABSTRAK

Gerakan kapal menggerakkan tangki kargo kapal disebabkan oleh ombak kuat, yang menyebabkan beban hentakan pada dinding tangki dan kemudian mempengaruhi pergerakan kapal. Berfokus pada platform pengembangan Operasi dan Manipulasi Lapangan Terbang (OpenFOAM) dari sumber terbuka Dinamika Fluid Dinamik (CFD), pengiraan berangka pergerakan kapal dengan tangki pemendapan dicapai bersama simulasi dan verifikasi berangka yang berkaitan dilakukan. Untuk proses ini, interaksi pengurangan gelombang dan tangki diambil kira sepenuhnya. Gerakan cecair pada tangki membran pertama disimulasikan melalui gerakan darjah kebebasan enam darjah. Tahap pengisian cecair ditetapkan masing-masing 25%, 50%, 75% dan 90% dari isipadu tangki, untuk mencari kes tekanan paling tinggi. Kemudian, simulasi dilanjutkan dengan mensimulasikan dengan menggunakan pengkadang untuk mengawal tekanan hentaman maksimum pada tangki membran. Penemuan utama adalah: tekanan impak untuk tahap pengisian LNG sebanyak 75% adalah paling tinggi berbanding dengan tahap pengisian yang lain. Kesan tekanan maksimum untuk baffle kombinasi berkurang sebanyak 28% berbanding dengan kes tangki tanpa penghadang.

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TABLE OF CONTENTS

		PAGE
DECLARATION		**II**
DEDICATION		**IV**
ABSTRACT		**V**
ABSTRAK		**VI**
ACKOWLEDGEMENT		**V1I**
TABLE OF CONTENT		**VIII**
LIST OF TABLES		**X**
LIST OF FIGURES		**XI**
LIST OF ABBREVIATIONS		**XIV**
LIST OF SYMBOLS		**XV**
CHAPTER		
1.	**INTRODUCTION**	**1**
	1.1 Background of Study	1
	1.2 Problem Statement	3
	1.3 Objective	3
	1.4 Scope of Project	4
	1.5 General Methodology	4
2.	**LITERATURE REVIEW**	**6**
	2.1 LNG carrier	6
	2.2 Sloshing Motion in LNG Tank	8
	2.3 Tank Filling Level	10
	2.4 Numerical Simulation	15
	2.4.1 Computational Fluid Dynamic (CFD)	15
	2.4.2 OpenFOAM	17
	2.5 Baffles in the Tank	18
3	**METHODOLOGY**	**20**
	3.1 Geometry of LNG Tank	20

	3.2	Mesh of Tank	22
	3.3	Six Degree of Freedom	23
	3.4	Dynamic Deforming Mesh	30
	3.5	InterFOAM Solver	30
	3.6	Volume of Fluid (VOF)	32
	3.7	Model	33
	3.8	Material Properties	34
	3.9	Case Set-up	34
		3.9.1 Liquid Filling Level	34
		3.9.2 Types of Baffles	36
	3.10	Summary	39
4	**RESULTS AND DISCUSSION**		**40**
	4.1	Results on each level of LNG	40
		4.1.1 25% of LNG	41
		4.1.2 50% of LNG	47
		4.1.3 75% of LNG	53
		4.1.4 90% of LNG	59
	4.2	Comparison of sloshing motion with previous study	65
	4.3	Comparison between all filling levels	67
	4.4	Baffles	68
		4.4.1 Horizontal baffles	68
		4.4.2 Vertical baffles	73
		4.4.3 Combinatorial baffles	78
	4.5	Comparison between all types of baffles	83
5	**CONCLUSION**		84
	5.1	Conclusion	84
	5.2	Recommendation	85
REFERENCES			86
APPENDICES			89

LIST OF TABLES

TABLE	TITLE	PAGE
3.1	Dimension of LNG tank in full scale	20
3.2	Amplitude and frequency for translation	23
3.3	Amplitude and frequency for rotation	23
3.4	Material properties of LNG and air	34
3.5	Case of filling level	38

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Methane's LNG ship	2
1.2	Flow chart of the methodology	5
2.1	LNG Carrier's Ship	6
2.2	LNG Tank Shape	7
2.3	Panels used to determine the panel pressure	9
2.4	Distribution of pressure in the fluid domain and at the wall of the tank for low filling level	10
2.5	Distribution of pressure in the fluid domain and at the wall of the tank for intermediate filling level	11
2.6	Distribution of pressure in the fluid domain and at the wall of the tank for high filling level	12
2.7	Time history of every filling level at T = 1.6 s	13
2.8	Geometry of the investigated tank	15
2.9	2D LNG tank with vertical baffle	29
3.1	Geometry of LNG tank according to the dimensions	21
3.2	Orthographic view of LNG tank	21
3.3	Mesh of LNG tank	22
3.4	Translation graph in X-direction of LNG tank against time	24
3.5	Translation graph in Y-direction of LNG tank against time	25
3.6	Translation graph in Z-direction of LNG tank against time	26
3.7	Rotation graph in X'- direction of LNG tank against time	27
3.8	Rotation graph in Y'- direction of LNG tank against time	28
3.9	Rotation graph in Z'- direction of LNG tank against time	29
3.10	Four different percentage of LNG level in tank	35

3.11	Types of baffles inside the LNG tank	36
4.1	Phase diagram of LNG tank	40
4.2	Pressure diagram of air and LNG	41
4.3	Phase fraction at t = 5 s until t = 20 s	42
4.4	Phase fraction at t = 25 s until t = 40 s	43
4.5	Pressure at t = 5 s until t = 20 s	44
4.6	Pressure at t = 25 s until t = 40 s	45
4.7	Pressure of 25% filling level of LNG against time	46
4.8	Phase fraction at t = 5 s until t = 20 s	48
4.9	Phase fraction at t = 25 s until t = 40 s	49
4.10	Pressure at t = 5 s until t = 20 s	50
4.11	Pressure at t = 25 s until t = 40 s	51
4.12	Pressure of 50% filling level of LNG against time	52
4.13	Phase fraction at t = 5 s until t = 20 s	54
4.14	Phase fraction at t = 25 s until t = 40 s	55
4.15	Pressure at t = 5 s until t = 20 s	56
4.16	Pressure at t = 25 s until t = 40 s	57
4.17	Pressure of 75% filling level of LNG against time	58
4.18	Phase fraction at t = 5 s until t = 20 s	60
4.19	Phase fraction at t = 25 s until t = 40 s	61
4.20	Pressure at t = 5 s until t = 20 s	62
4.21	Pressure at t = 25 s until t = 40 s	63
4.22	Pressure of 90% filling level of LNG against time	64
4.23	Phase fraction of present result and Wei Wang et al (2014) at t = 10 s of 25% of LNG	65
4.24	Phase fraction of present result and Wei Wang et al (2014) at t = 10 s of 50% of LNG	66
4.25	Phase fraction of present result and Wei Wang et al (2014) at t = 10 s of 25% of LNG	66
4.26	Pressure of each filling level of LNG against time	67
4.27	Pressure of LNG with horizontal baffles against time	68
4.28	Phase fraction at t = 5 s until t = 20 s	69
4.29	Phase fraction at t = 25 s until t = 40 s	70

4.30	Pressure at t = 5 s until t = 20 s	71
4.31	Pressure at t = 25 s until t = 40 s	72
4.32	Pressure of LNG with vertical baffles against time	73
4.33	Phase fraction at t = 5 s until t = 20 s	74
4.34	Phase fraction at t = 25 s until t = 40 s	75
4.35	Pressure at t = 5 s until t = 20 s	76
4.36	Pressure at t = 25 s until t = 40 s	77
4.37	Pressure of LNG with combinatorial baffles against time	78
4.38	Phase fraction at t = 5 s until t = 20 s	79
4.39	Phase fraction at t = 25 s until t = 40 s	80
4.40	Pressure at t = 5 s until t = 20 s	81
4.41	Pressure at t = 25 s until t = 40 s	82
4.42	Pressure difference between baffles’ types against time	83

LIST OF ABBREVIATIONS

LNG	-	Liquefied Natural Gas
CFD	-	Computational Fluid Dynamics
2D	-	2 Dimensional
3D	-	3 Dimensional
VOF	-	Volume of Fluid
FDA	-	Food and Drug Administration

LIST OF SYMBOLS

ω	-	Angular frequency
f	-	Frequency
μ	-	Kinematic viscosity
ρ	-	Density
σ	-	Surface tension coefficient
κ	-	Curvature of surface interface
X_g	-	Displacement of mesh nodes
γ	-	Diffusivity
r	-	Distance between cell to the moving boundary
u	-	Velocity
p	-	Pressure
g	-	Gravity
Fs	-	Surface tension force
A	-	Amplitude

CHAPTER 1

INTRODUCTION

1.1 Background

LNG is the acronym for liquefied natural gas that has been made over millions of years of transformation of organic materials, such as plankton and algae. LNG is natural gas that has been cooled down to liquid form for safety and ease of non-pressurized storage. It is odorless, colorless, non-toxic and non-corrosive. LNG is normally stored in insulated tank at atmospheric pressure and typically boil slowly about giving off 0.10% - 0.15% of volume per day.

The beginnings of LNG's water bones started in 1950, Union Stockyards, Chicago and Continental Oil explored an early concept for the transportation and the uses of LNG. They planned to buy the gas in Gulf Coast, then liquefy it. After that, transport the oil to Chicago by the water and vaporize it for refrigeration by the cold in food processing industry and also make the gas available for using in the industrial field.

The *Methane* was built in Ingalls Shipyard with a capacity of cargo of 5,550 cubic meters and the purpose is to run on the Mississippi transportation of LNG north to Chicago. That current initial economics was looking good, but, due to the fear of contaminating the food product, Food and Drug Administration (FDA) was refused to give the permit to the concepts. The starting back of shipping the LNG happened when Continental choose to continue the operation of LNG and found the gas can be liquefied at Gulf coast, and then being transported to east Coast by water. After that, LNG was vaporized and they put into the main competitive and pipelining.

Figure 1.1 Methane's LNG ship (Zalar et al., 2005)

LNG's first regasification and production facilities in United States have been started operating in Cleveland, Ohio in year 1941. The facility is commonly called a top plant's shaving. Since then, there are over hundred facilities in U.S which is situated near the centers of high request of natural gas.

Since the mid 1970's, the size and the design of LNG carriers has remained relatively constant. The largest of these "conventional" carriers transport LNG cargoes ranging from 125000 m^3 to 145,000 m^3. Over this duration, the design and cost improvements were approximately incremental.

1.2 Problem Statement

Liquified Natural Gas (LNG) is transported by LNG ships and it will slosh in partially filled tanks. This will cause damage to tank structures. For examples, the tank structures will become cracks and fatigue, and it will affect the ship's stability.

Sloshing motion in a partially filled tank will be violent in certain condition. For instance, the frequency of the motion of the LNG tank is equal or closed to the natural frequency of the interaction between the LNG and the tank structure. So, there is a demand that the LNG carrier should be safely operated at all liquid filling level.

1.3 Objective

The objectives of this project are as follow:

a) To model sloshing phenomenon of LNG tank on the six degrees of freedoms motion responses using open source CFD software.

b) To investigate the effect of 25%, 50%, 75% and 90% filling capacity on pressure.

c) To analyze baffle design on reducing the pressure.

1.4 Scope of project

The scopes of present study are:

a) Sloshing motion analysis will be using numerical simulation only.

b) 3D geometry of sloshing tank.

c) Baffles design in the sloshing tank to reduce the sloshing load.

1.5 General methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Select any related journals, articles or any other materials regarding this project and will be reviewed in the report.

2. Simulation

   Simulation of the Computational Fluid Dynamic (CFD) to get see the flow pattern in sloshing tank.

3. Analysis and proposed solution

   Analysis will be presented on how the sloshing tank level will affects the membrane tank. Solution will be presented based on the analysis of the baffles in the tank.

4. Report writing

   A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.2.

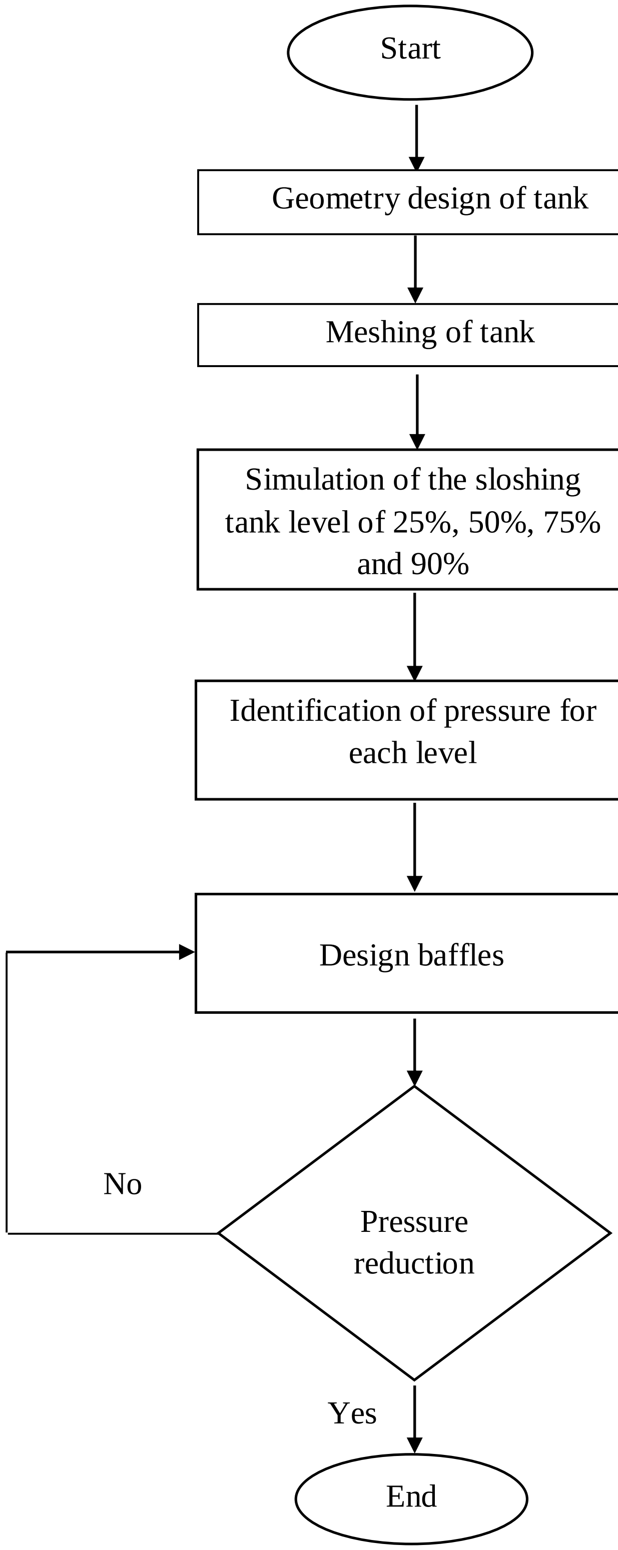

Figure 1.2 Flow chart of the methodology

CHAPTER 2

LITERATURE REVIEW

2.1 LNG carrier

As the liquefied natural gas (LNG) has increased in demand, LNG carrier continues and remain to experience astounding growth. The LNG shipper is a tank carrier invented for specific purpose which is transporting LNG and have commonly managed with fully tank loaded or a minimal loaded during the return voyages is at ballast. Figure 2.1 shows the LNG carrier's ship.

Figure 2.1 LNG Carrier's Ship (Zalar et al., 2005)

The common stuffing level of LNG tank is exceeding 95% tank height at the chock-full loaded condition and also below 5% at the condition of ballast (Kim et al., 2002). Afterwards the reconciliation of a broad chamfer on the top of tank. Then, augmented the insulation structure on the above part of tank that has been formed, the present design run-through which are underside scantling and padding system that has remained witnessed as a safe tank to a sloshing weight impact on some restricted operative circumstances (Tanaka et al., 1984). In the premature designs of LNG tank with a slighter smaller chamfer and decrepit padding scheme disclosed some amount of minimal compensations on padding part and the efficacy devices in tank as in Figure 2.2. Nonetheless, there is no indemnities have been informed in as much as the rise area of chamfer dimension and the strengthening of padding structure (Kim et al., 2002).

Figure 2.2 LNG Tank Shape (Kim et al., 2002)

2.2 Sloshing motion in LNG tank

Sloshing occurrence is a great conjectural and hands-on practical on importance in the littoral and offshore industrial with the considering to sea's safety on transporting the oils and LNG. Sloshing in a heavy sea waves may urge the physical damages toward the tank ramparts and also may distress the immovability of tank. Ship gestures are triggered by the convoluted contact between peripheral forces that wielded by the ocean waves on the underside of the body and also the forces exerted by the sloshing fluid inside the membrane ship tank (Peric, 2009).

Large deformation and impulsive pressure on the internal structure of tank happens because of the violent flow of the sloshing liquid in the tank. This happened when the external wave frequency is close to the motion of the ship with partially filled tanks. The excite motion of the ship will affect the loading impact since it is very sensitive to the motion.

There are some of the researchers done about the sloshing tanks just before the consideration on the effect of tank sloshing. Mikelis et al., (1984) have used a 2D finite element difference transient method to solve the pressure and the motion of liquid cargo. Other than that, Rognebakke and Faltinsen, (2000) were conducting a 2D experiments on the hull part that contain some tanks that filled with amount of water that excited by the waves. He also conducted the simulated model case by using the linear and non-linear sloshing model.

Kim et al. (2002) make a partition on the surface of tank by putting the number of panels as in Figure 2.3. The arrangement of every panels is determined from the typical arrangement of girders. Two of the numbers are defined at every panel. The maximum panel pressure is well-defined as the maximum value of the pressure's impact on the panel. Besides, immediate average impact pressure is the description of the average panel. It is a