

THERMAL STRESS ANALYSIS FOR EXHAUST HEAT EXCHANGER

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ABSTRACT

Thermal stress induced in an object or structural member by restraint against movement is required to accommodate temperature changes. In this paper, the thermal stress and deformation of the exhaust heat exchanger on board a ship is analysed. The flow and temperature distributions of exhaust heat exchanger are conducted in ANSYS Static Structural by the coupled analysis of fluid and solid zones. According to the numerical analysis it is found that the thermal stress is increasing non-linearly with the increase of inlet sea water temperature. By increasing inlet sea water temperature will increase thermal stress. The result indicates that the maximum stress is equal to 479 MPa which is exceed the yield stress. Therefore, current heat exchanger being used is insufficient in design. By varying the different sea water inlet temperature and sea water inlet pressure at allowable limit still shows that maximum Von Misses Stress for current design is exceeding yield stress. The new design is proposed by increasing of thickness plate from 2mm to 3mm and proven to produce maximum Von Misses Stress below the yield stress which is equal to 245MPa. Percentage area for total thermal stress is also much lower compare to current design.

ABSTRAK

Tegasan haba ke atas sesuatu objek atau bahagian struktur yang disebabkan oleh sekatan terhadap pergerakan diperlukan untuk menampung perubahan suhu. Dalam kajian ini, tekanan haba dan perubahan bentuk ke atas penukar haba ekzos kapal telah dianalisa. Pengaliran suhu dan aliran penyejuk pada penukar haba ekzos dianalisis menggunakan ANSYS Static Structural dengan menggabungkan kedua-dua analisis ke atas zon cecair dan zon struktur. Menurut analisis berangka didapati bahawa tekanan haba semakin meningkat secara tidak linear dengan peningkatan suhu kemasukan air laut. Dengan meningkatkan suhu kemasukan air laut akan meningkatkan tegasan haba. Keputusan telah menunjukkan bahawa tegasan haba maksimum adalah sama dengan 479 MPa yang melebihi tegasan alah material yang digunakan. Justeru, penukar haba yang digunakan ketika ini didapati tidak memenuhi keperluan pengoperasian dalam aspek reka bentuk. Dengan mengubah pelbagai parameter suhu masuk air laut dan tekanan masuk air laut pada julat yang dibenarkan didapati maksimum Von Misses Stress masih melebihi melebihi tegasan alah material tersebut. Oleh itu, reka bentuk baru telah dicadangkan dengan meningkatkan ketebalan plat dari 2mm kepada 3mm dan terbukti menghasilkan maksimum Von Misses Stress 245 MPa iaitu dibawah tegasan alah material. Peratusan kawasan bagi keseluruhan tegasan haba juga jauh lebih rendah berbanding dengan reka bentuk sekarang.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	
	ACKNOWLEDGEMENTS	i
	ABSTRACT	ii
	ABSTRAK	iii
	TABLE OF CONTENTS	iv
	LIST OF TABLES	vi
	LIST OF FIGURES	vii
	LIST OF SYMBOLS	ix
1	INTRODUCTION	
	1.1 Research Background	4
	1.2 Research Objectives	5
	1.3 Problem Statement	5
	1.4 Scope of Research	7
	1.5 Theoretical Framework	7
	1.6 Organization of Thesis	8
2	LITERATURE REVIEW	
	2.1 Introduction	9
	2.2 Type of Heat Exchanger	9
	2.3 Heat Exchanger Performance	10
	2.3.1 Flow Maldistribution	10
	2.3.2 Fouling	13
	2.3.3 Pressure Drop	14
	2.3.4 Thermal Analysis	14
	2.4 Heat Exchanger Optimization	15

3	RESEARCH METHODOLOGY	
3.1	Introduction	18
3.2	Research Methodology Flow Chart	19
3.3	Identification of Research Variables	20
3.4	Data Collection	21
3.5	Development CFD Model and CSD Model	21
3.6	Analysis on Fluid Flow and Structure	27
3.7	Propose The Sufficient and Practical Design	28
3.8	Governing Equation	28
4	RESULTS AND DISCUSSION	
4.1	Introduction	31
4.2	Current Operating Condition	31
4.3	Von Misses Stress and Deformation Analysis	34
4.4	Temperature and Pressure Distribution for Every Variables	36
4.5	Thermal Stress and Deformation for Every Variables	37
4.6	Von Misses Stress and Deformation Area Percentage	38
4.7	Stresses at Angular Point	40
4.8	Mitigation Plan	41
5	CONCLUSION AND RECOMMENDATION	
5.1	Conclusion	44
5.2	Recommendation	45
	REFERENCES	46

LIST OF TABLES

TABLE NO	TITLE	Page
2.1	CFD Simulations In Fluid Flow Maldistribution	11
2.2	Matrixes of Literature Review On Heat Exchanger Analysis	17
3.1	Meshing Characteristic	24
3.2	ANSYS CFX Boundary Zones Setup	24
3.3	ANSYS Static Structural Boundary Zones Setup	26
3.4	Variables and Non Variables on Analyzing Exhaust Heat Exchanger	28
4.1	ANSYS CFX and ANSYS Static Structural Analysis by Changing Sea Water Inlet Cooling Temperature	35
4.5	ANSYS CFX and ANSYS Static Structural Analysis By Changing Sea Water Inlet Cooling Pressure	36

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Location of Above Water Exhaust Heat Exchanger and Below Water Exhaust Heat Exchanger.	2
1.2	Layout Arrangement of Exhaust Cooling Valve	3
1.3	Functionality of Exhaust Cooling Valve	4
1.4	Exhaust Heat Exchanger Temperature	6
1.5	Area of Crack at Exhaust Heat Exchanger	6
1.6	Theoretical Framework	7
2.1	Classification of Heat Exchangers on the basis of construction	10
3.1	Research Methodology Flow Chart	20
3.2	Boundary Zone of Geometrical Model	22
3.3	Edge Area of Meshing	23
3.4	ANSYS Static Structural Meshing	23
3.5	Structure of Fluid and Solid Interaction	25
4.1	Graph Main engine RPM vs Exhaust Gas Temperature	32
4.2	Contour of Pressure and Temperature Distribution	33
4.3	Contour of Von Misses Stress and Deformation	35
4.4	Sea Water Inlet Temperature vs Maximum Von Misses Stress	38
4.5	Sea Water Inlet Pressure vs Maximum Von Misses Stress	38

4.6	Sea Water Inlet Cooling Temperature vs Percentage Area Exceed Yield Stress	39
4.7	Sea Water Inlet Cooling Pressure vs Deformation Percentage Area	40
4.8	Graph Stress at Angular Point	40
4.9	Contour of Thermal Stress for Recommended Design	42
4.10	Contour of Deformation for Recommended Design	42
4.13	Stress At Angular Point for Recommended Design	43

LIST OF SYMBOLS

	-	Von Misses Stress
$\epsilon_x, \epsilon_y, \epsilon_z$	-	Normal Strain
μ	-	Poisson's Ratio
τ_t	-	Sheer Stress
α	-	Thermal expansion coefficient
Q	-	Heat transfer rate,
E	-	Young's modulus
x, y, z	-	Coordinate directions
d_i	-	Inner diameter of inner tube
d_o	-	Outer diameter of inner tube
D_i	-	Inner diameter of outer tube
D_o	-	Outer diameter of outer tube
ρ	-	Density

CHAPTER 1

INTRODUCTION

Sea water cooling system are widely used for exhaust gas before being discharged to the exterior by Royal Malaysian Navy. An example ship that use kind of system are corvette, mine counter measure vessel, new generation petrol vessel and frigate. Currently corvette ship use butterfly valve provided with sea water cooling jacket to refrigerate the engine gas.

Particulate emission from diesel engines is receiving a great deal of attention due to its probable carcinogenic property. In the exhaust pipe of a diesel engine, the change of the exhaust gas temperature can result in nucleation and condensation of volatile materials and coagulation of particulates.

During startup phase the propulsion engine exhaust is carried away through the above sea level outlet by positioning the on line butterfly valve open (300 in dia), while the butterfly valve (600 in dia), mounted on the underwater projecting duct, is in close position. This valve position also occurs when the ship moves on reverse gear or, anyhow, during manouvering or moving forward slowly.

When the engines develop full power and during the normal navigation the butterfly valve (600 in dia) on the below sea level outlet remains open and the butterfly valve on the above sea level outlet is held closed.

Characteristic Data:

Max exhaust pressure - 2.5 bar

Max operational exhaust temperature- 700°C

Operating sea water pressure - 1.5 bar

Plate Thickness - 2mm

Material - Stainless Steel

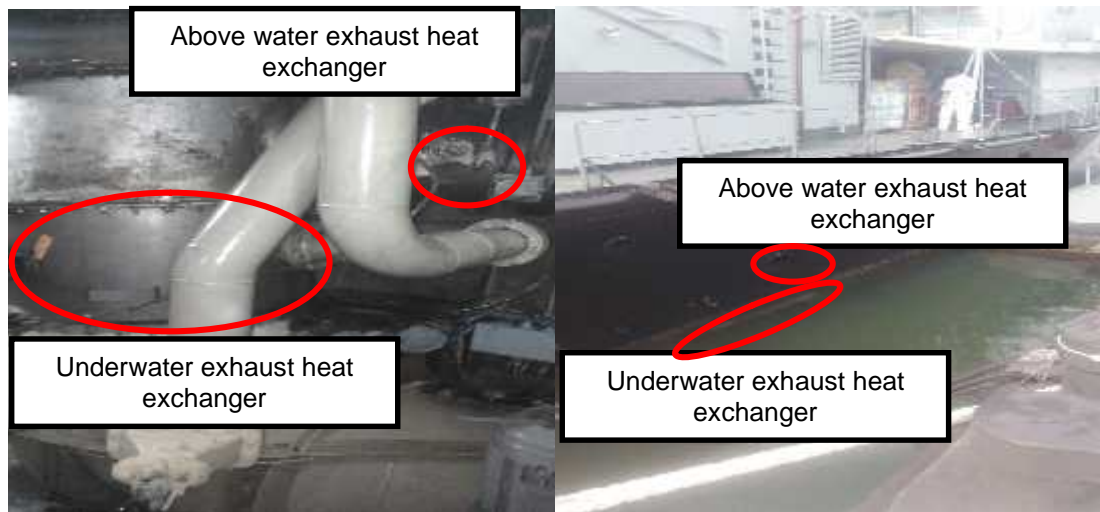


Figure 1.1: Location of Above Water Exhaust Heat Exchanger and Below Water Exhaust Heat Exchanger.

The engine gas (flue gas) is refrigerated before being discharged to the exterior, the two flue outlets provided, one above and one below the sea level respectively, are provided with sea water cooling jacket as Figure 1.1.

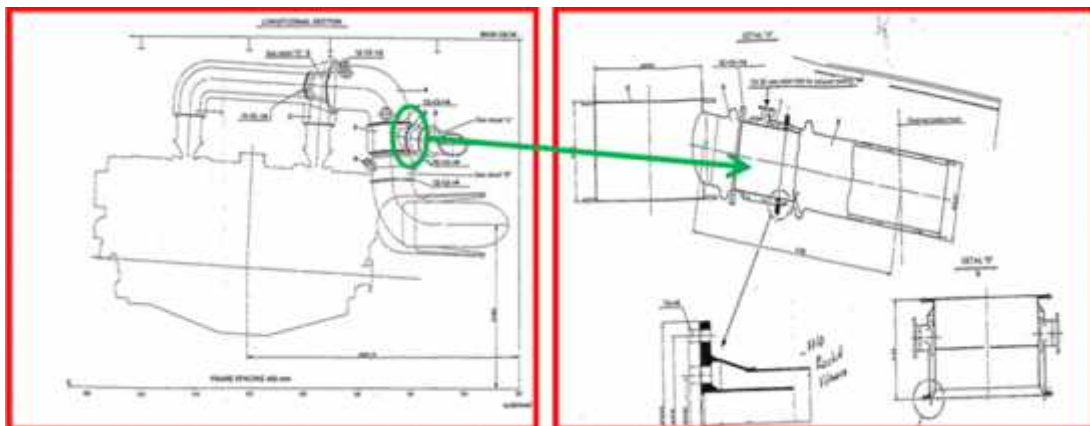


Figure 1.2: Layout Arrangement of Exhaust Cooling Valve

The effect of this refrigeration causes remarkable decrease in the exhaust gas volume that makes its mixing sea water much easier; such a mixing also facilitated by the shape of the flue outlet which directs the flue gas as much parallel as possible to the flow line along the ship's immersed hull as shown in Figure 1.2. The longitudinal axis of the exhaust duct end is not normal to the ship side; it is instead bent astern.

This feature, while facilitating the engine exhaust when the ship is moving ahead will affect negatively the discharge of these combustion products when the ship moves on reverse. In this circumstance it is mandatory that the exhaust gas be routed through the pipe with outlet above sea level.

The material used to fabricate the butterfly exhaust valve is stainless steel, X8CrNi310-UNI 6900/71 (AISI 321). Parts are fabricated from sheets and assembled by longitudinal welding process. In the areas that are not refrigerated by sea water, the exhaust ducts and relative assembly flanges are fabricated.

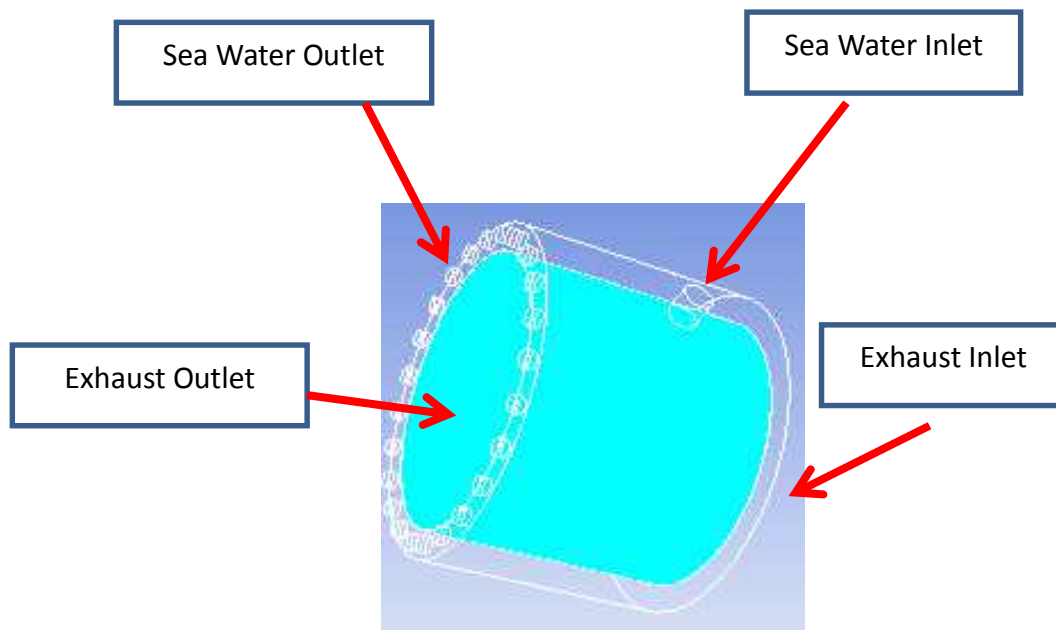


Figure 1.3: Functionality of Exhaust Cooling Valve

1.1 Research Background

Based on my research, it has been found that CFD has been employed for the following areas of study in various types of heat exchangers: fluid flow maldistribution, fouling, pressure drop and thermal analysis in the design and optimization phase. As presented by Muhammad Aslam Bhutta [1].

The quality of the solutions obtained from these simulations are largely within the acceptable range proving that CFD is an effective tool for predicting the behavior and performance of a wide variety of heat exchangers.

Analysis of flow is a major consideration of my topic. This is proven based on research by Jiang when they found Non-uniformity in fluid flow is one of the primary reasons resulting in a poor heat exchanger performance. This may be attributed to improper design of inlet/outlet port and header configuration, distributor construction and plate corrugations [2].

Heat distribution is affected to thermal stress. As found by Irfan and Chapman [3] where hot spots in the axial temperature gradient were a major source of thermal stress. All that research become my preference to solve my problem.

1.2 Research Objectives

Research objectives of this study are as follow:

- a. To verify current design of exhaust heat exchanger in term of reliability and sufficiency.
- b. To propose improvement of current design in order to reduce thermal stress and deformation.

1.3 Problem Statement

Always happen above water cooling exhaust become overheated during main engine is operated below 900rpm or engine rpm is not consistent. Engine room become very hot and temperature above 60°C. As shown in Figure 1.4 temperature of exhaust cooling valve outer tube can reached about 153°C during slow speed. Thus affected to personnel comfortability during working condition. Furthermore temperature rising had contributed to overall ship infrared signature.



Figure 1.4: Exhaust Heat Exchanger Temperature

The worst case scenario happen if ship constantly sailing 2 time a month sailing, the exhaust heat exchanger always crack at welded joint as shown in Figure 1.5. Frequent time average once in 3 month. The water discharge outboard also not consistent and intermittent especially if main engine rpm is increased and decreased frequently. Therefore, it is crucial to identify fluid flow maldistribution, fouling, pressure and thermal analysis in the design and optimization phase.



Figure 1.5: Area of Crack at Exhaust Heat Exchanger

1.4 Scope of research

Scopes of research are as follows:

- a. Temperature distribution and pressure distribution of cooling water for various input temperature and pressure.
- b. Thermal stress and deformation various input temperature and pressure.
- c. Numerical method on simplify model and compare with current condition.

1.5 Theoretical Framework

The theoretical framework of this research is presented in **Figure 1.6**. The critical steps are during methodology process. Initial and boundary condition must be defined correctly.

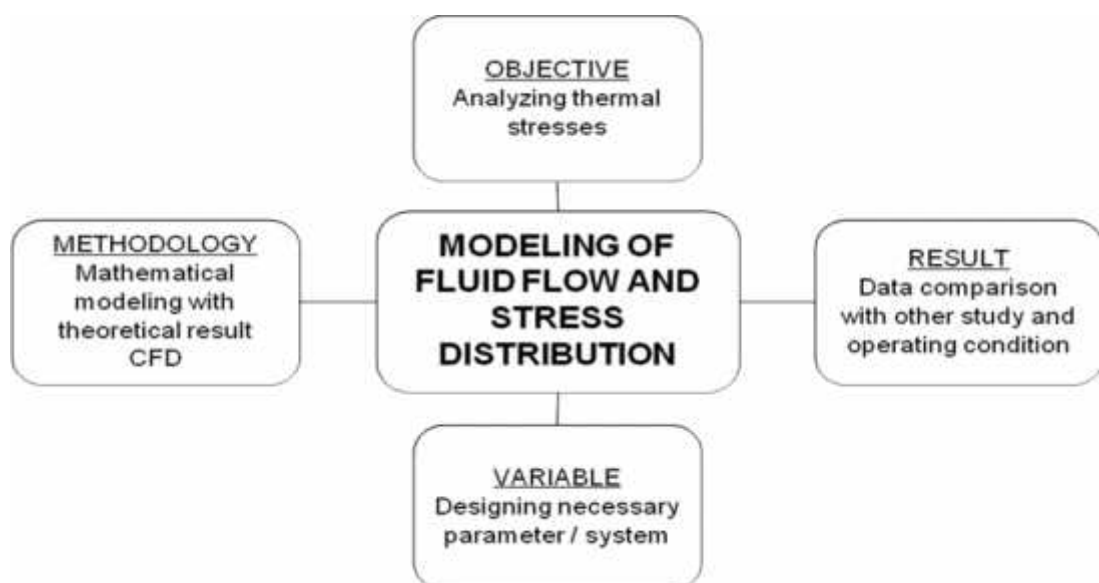


Figure 1.6: Theoretical Framework

1.6 Organization of Thesis

Chapter 1: Introduction

This chapter describes the research background of this. The objective of this project also been started in this chapter.

Chapter 2: Literature Review

In this chapter, the item that will be discussed is the related works and literature review that will supported this study.

Chapter 3: Methodology

The most significant chapter that is chapter 3 detailing on the research methodology variables and equations involved in the modelling and simulation part. Data collection method and the accuracy of the result are been listed in this chapter . It will also define the research variable and the data to be enquired.

Chapter 4: Result and Discussion

For this chapter, results and findings obtained from the FSI modelling are listed out and discussion is carried out for the result obtained. the reliability of the data obtained will also be discussed

Chapter 5: Conclusion and Recommendation

In this last chapter it is dedicated for conclusion of the study and recommendations on future improvements for different operating parameters needed in this study. This paper will have the reference list post.

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