

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS ♦

JUDUL: STUDY ON CRACK INTERACTION EFFECT OF API STEEL USING FINITE ELEMENT ANALYSIS

SESI PENGAJIAN: 2011/2012

Saya, **AHMAD SYAUQI FATHUDDIN MD SHAIMI (890220-11-5123)**
(HURUF BESAR)

Mengaku membenarkan tesis (Sarjana Muda/ ~~Sarjana~~/Doktor Falsafah)* ini disimpan di perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis ini adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi Pengajian tinggi.
4. **Sila tandakan (√)

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:

Kg. Gong Kasim, Merchang,
21610 Marang,
Terengganu

PN. NORHAIDA ABD RAZAK
(Nama Penyelia)

Tarikh: **25 JUN 2012**

Tarikh: **25 JUN 2012**

CATATAN:* Potong yang tidak berkenaan.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/ organisasi Berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

- ♦ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

STUDY ON CRACK INTERACTION EFFECT OF API STEEL USING FINITE
ELEMENT ANALYSIS

AHMAD SYAUQI FATHUDDIN BIN MD SHAIMI

Report submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled “Study on Crack Interaction Effect of API Steel Using Finite Element Analysis” is written by Ahmad Syauqi Fathuddin Bin Md Shaimi. I have examined the final copy of this project and in our opinion, it is fully adequate in terms of scope and quality for the award of degree of Bachelor Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor Mechanical Engineering.

(Mr. Luqman Hakim Bin Ahmad Shah)

Examiner

Signature

SUPERVISOR'S DECLARATION

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

Signature :

Name of Supervisor : MRS. NORHAIDA BINTI ABD RAZAK

Position : LECTURER

Date : 25th June 2012

STUDENT'S DECLARATION

I declare that this report titled "Study on Crack Interaction Effect of API Steel using Finite Element Analysis" is my result of my own research except as stated in the references. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : AHMAD SYAUQI FATHUDDIN BIN MD SHAIMI

ID Number : MA08125

Date : 25th June 2012

TABLE OF CONTENTS

		Page
EXAMINER’S DECLARATION		ii
SUPERVISOR’S DECLARATION		iii
STUDENT’S DECLARATION		iv
DEDICATIONS		v
ACKNOWLEDGEMENTS		vi
ABSTRACT		vii
ABSTRAK		viii
TABLE OF CONTENTS		ix
LIST OF TABLES		xii
LIST OF FIGURES		xiii
LIST OF SYMBOLS		xvi
LIST OF ABBREVIATIONS		xvii
CHAPTER 1 INTRODUCTION		
1.1	Introduction	1
1.2	Project background	1
1.3	Problem statement	3
1.4	Objectives	3
1.5	Scope of study	3
CHAPTER 2 LITERATURE REVIEW		
2.1	Introduction	4
2.2	Introduction to pipeline	4
2.3	Pipeline transported substance	5
2.4	Material properties of pipeline	6
	2.4.1 Materials	6
	2.4.2 Properties and composition of copper	8
	2.4.3 Carbon steel	10

2.5	Malaysian standard	11
2.6	Failure in pipeline	12
	2.6.1 Introduction	12
	2.6.2 Stress corrosion cracking (SCC)	13
	2.6.3 Hydrogen induced cracking (HIC)	15
	2.6.4 Stress-oriented hydrogen induced cracking (SOHIC)	16
	2.6.5 Sulfide stress cracking (SSC)	16
2.7	Causes of pipeline failure	17
2.8	Failure criterion	24
	2.8.1 Maximum Shear Stress (MSS)	24
	2.8.2 Von Mises Stress (VMS)	25
2.9	Finite Element Analysis	26

CHAPTER 3 METHODOLOGY

3.1	Introduction	28
3.2	Flow chart methodology	28
3.3	Procedure	30
	3.3.1 Material properties	31
	3.3.2 Modeling design	32
	i. Geometry	32
	ii. Elements	36
	iii. Loads / Boundary conditions	37
	iv. Define element properties	38
	v. Element properties	40
	vi. Performing analysis	41

CHAPTER 4 RESULT AND DISCUSSION

4.1	Introduction	43
4.2	Result	44
	4.2.1 Effect of pressure defect along the crack path	44
	4.2.2 Variation of pressure on defect and Von Mises stress	55

4.3	Discussion	60
	4.3.1 Von Mises stress	60
	4.3.2 Yield Strength of material	61
	4.3.3 Summary	62

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Introduction	63
5.2	Conclusion	63
5.3	Recommendations	64

REFERENCES 65

APPENDICES

A	Project Planning (Gantt Chart)	68
B	Simulation Drawing	70
C	Von Mises Stress and Pressure on Defect Data	71

LIST OF TABLES

Table No.	Title	Page
2.1	Comparison of properties of various pipeline materials	7
2.2	Typical chemical analyses of copper	9
2.3	Physical properties of copper	9
3.1	Mechanical properties of the API X65 steel	31
3.2	The geometry of the defects	33
4.1	Maximum von Mises stress and pressure on crack	60
6.1	Analysis data for case 1	71
6.2	Analysis data for case 2	71
6.3	Analysis data for case 3	72
6.4	Analysis data for case 4	73
6.5	Analysis data for case 5	73
6.6	Analysis data for case 6	74
6.7	Analysis data for case 7	75
6.8	Analysis data for case 8	75
6.9	Analysis data for case 9	76
6.10	Analysis data for case 10	77

LIST OF FIGURES

Figure No.	Title	Page
2.1	Seawater pipeline systems	8
2.2	Pressurize in a pipeline	13
2.3	Stress corrosion cracking	14
2.4	Formation of hydrogen sulphide	15
2.5	Pipeline steel after sulfide stress cracking	17
2.6	Gas pipeline that failed due to external mechanical damage	18
2.7	Gouge near the midpoint of the rupture	18
2.8	A cross section through the gouge	19
2.9	SEM fractograph of fatigue damage	20
2.10	Inside surface at the failure origin of a 20-inch pipeline	21
2.11	Fracture surface in the pipeline	21
2.12	Two clusters of crack indications	22
2.13	Surface of crack broken	22
2.14	Microstructure in area of secondary crack	23
2.15	Hydrostatic test rupture of seamless	23
2.16	Maximum Shear Stress criteria	24
2.17	Comparison of Von Mises and Maximum Shear Stress criteria	26
3.1	Overall flowchart	29
3.2	Methodology flowchart	30
3.3	True stress strain curve of API X65	31
3.4	Variables of the model	32
3.5	Quarter radius of cylinder model	34
3.6	Creating crack	35
3.7	Crack modeling	35
3.8	Creating Mesh	36
3.9	Creating Mesh Seed	36
3.10	Equivalencing	37
3.11	Geometrical modeling with P_o and P_d	38

3.12	Creating fields	39
3.13	Properties of elastic	39
3.14	Properties of plastic	40
3.15	Creating element properties	41
3.16	Creating job step analysis	42
4.1	Graph Von Mises stress vs normalized crack distance for case 1	44
4.2	Deformation of True Stress Strain for case 1	45
4.3	Graph Von Mises stress vs normalized crack distance for case 2	46
4.4	Graph Von Mises stress vs normalized crack distance for case 3	46
4.5	Graph Von Mises stress vs normalized crack distance for case 4	47
4.6	Deformation of True Stress Strain for case 2	48
4.7	Deformation of True Stress Strain for case 3	48
4.8	Deformation of True Stress Strain for case 4	48
4.9	Graph Von Mises stress vs normalized crack distance for case 5	49
4.10	Graph Von Mises stress vs normalized crack distance for case 6	50
4.11	Graph Von Mises stress vs normalized crack distance for case 7	50
4.12	Deformation of True Stress Strain for case 5	51
4.13	Deformation of True Stress Strain for case 6	51
4.14	Deformation of True Stress Strain for case 7	52
4.15	Graph Von Mises stress vs normalized crack distance for case 8	53
4.16	Graph Von Mises stress vs normalized crack distance for case 9	53
4.17	Graph Von Mises stress vs normalized crack distance for case 10	54
4.18	Deformation of True Stress Strain for case 8	54
4.19	Deformation of True Stress Strain for case 9	55
4.20	Deformation of True Stress Strain for case 10	55
4.21	Maximum von Mises stress in the inlaminar region as a function of the pressure on the defect for, $r_i = 6.35$ mm	56
4.22	Maximum von Mises stress in the inlaminar region as a function of the pressure on the defect for $r_i = 38$ mm	57
4.23	Maximum von Mises stress in the inlaminar region as a function of the pressure on the defect for $r_i = 63.5$ mm	58
4.24	Maximum von Mises stress in the inlaminar region as a function of the pressure on the defect for $r_i = 89$ mm	59

6.1	Sample of Simulation Model	70
6.2	Sample of Crack on Model	70

LIST OF SYMBOLS

mm	Millimeter
MPa	Mega Pascal
%	Percent
kN	Kilo newton
σ	Stress
P_o	Operational Pressure
P_d	Pressure on Defect
E	Young Modulus
UTS	Ultimate Tensile Strength
Y	Yield Strength
e	Strain
Cu	Cuprum
H ₂	Hydrogen
O ₂	Oxygen
°C	Degree Celsius
kg	Kilogram
GPa	Giga Pascal
K	Kelvin
m	Meter
λ	Modulus Elasticity
ν	Poisson's Ratio
r_d	Curvature of the defect on the right side
r_i	Curvature of the defect on the left side
d_y	Vertical separation
d_x	Horizontal separation

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
API	American Petroleum Institute
MS	Malaysian Standard
LPG	Liquefied Petroleum Gas
NG	Natural Gas
ANSI	American National Standards Institute
HIC	Hydrogen Induced Cracking
SCC	Stress Corrosion Cracking
SWC	Stepwise Cracking
SOHIC	Stress-Oriented Hydrogen Induced Cracking
SSC	Sulfide Stress Cracking
AF	Acicular Ferrite
FP	Ferrite-Pearlite
MSS	Maximum Shear Stress
VMS	Von Mises Stress
2D	Two Dimension