

**DESIGN AND FINITE ELEMENT ANALYSIS OF
SOLID EXPANDABLE TUBULAR**

P.KHIDMAT MAKLUMAT AKADEMIK
UNIMAS



1000166059

ALUYAH BINTI SIPI

**This project is submitted in partial fulfillment of the requirement for
Bachelor of Engineering with Honours in Mechanical Engineering and
Manufacturing System**

**Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK**

2006

Dedicated to my lecturers.

ACKNOWLEDGEMENT

First of all, the author would like to show her gratitude to her supervisor, Dr. Mohammad Shahril Osman for all his help, supervision, constant encouragement, ultimately enthusiasm and great expectation. Without his guidance and dedicated effort in helping the author with this project, this project would not have been possible.

Special thanks to Dr. Mohammad Omar Abdullah for his assistance in the preparation of first part of this project. He provided the author with many hours of discussions concerning solid expandable tubular and its application in petroleum industry.

A special acknowledgement goes to her parents, Mr. Sipi bin Kitong and Mdm. Rosnah binti Abdullah for their encouragement and understanding in letting me complete this project.

Finally, the author wishes to thank Mr. Azizan bin Sipi and Mr. Mohammad Izam bin Abdullah for their great moral support along the way the author did her thesis.

To all of these wonderful people, I am pleased to express my gratitude.

ABSTRACT

Solid expandable tubular is the technology of casing design which enables operator to reach the total depth with a larger hole than a conventional casing while beginning the well with a smaller hole. In this project, the technology of solid expandable tubular and its application in the oil and gas industry nowadays will be described. This present work produces the designs which utilize CATIA. Axisymmetric modeling and analysis of the tubular is developed using finite element software ANSYS to determine maximum displacement and stress. The tubular was modeled as deformable body using a quadratic element. The finite element analysis is preceded by modeling the geometry of the solid tubular, applying material's properties and imposing the appropriate boundary conditions. The model has outer radius of 170 mm and wall thickness of 10mm. The elastic modulus and Poisson's ratio of the material is taken as 200 Gpa and 0.3 respectively. Axisymmetric analysis is chosen because it can reduce a three dimensional problem (3D) into a two dimensional (2D) ones. This will improve computation time and does not require large amount of nodes and element when simulating the model. The simulation results and calculation using Lamé's equation showed that the diameter of the tubular increase while the thickness of the tubular decrease after the expansion process. These results satisfy the theory and its application in oil well drilling and completion.

ABSTRAK

Tiub pepejal yang boleh mengembang merupakan salah satu teknologi dalam reka bentuk pelapik yang berfungsi sebagai dinding telaga minyak. Teknologi ini membolehkan syarikat yang mengendalikan penggerudian telaga minyak sampai kepada kedalaman sebenar telaga minyak dengan lubang yang lebih besar walaupun memulakan penggerudian dengan lubang yang kecil. Projek ini akan menerangkan tentang teknologi tiub pepejal yang boleh mengembang ini dan aplikasinya dalam industri penggerudian telaga minyak dan gas. Projek ini akan menghasilkan reka bentuk model tiub pepejal yang boleh mengembang menggunakan perisian CATIA. Permodelan dan analisis berdasarkan paksi simetri dilakukan melalui perisian elemen terhad atau unsur finit menggunakan aplikasi program ANSYS. Analisis elemen finit ini dilakukan untuk menentukan perubahan jejari dan tekanan maksimum pada dinding tiub selepas pengembangan. Model tiub tersebut direka menggunakan elemen kuadratik yang terdapat dalam program ANSYS. Jejari luar model tiub pepejal yang boleh mengembang itu ialah 170 mm manakala ketebalannya ialah 10 mm. Modulus kekenyalan dan nisbah Poisson ialah masing-masing 200 GPa dan 0.3. Analisis paksi simetri dipilih kerana ia boleh menukarkan masalah tiga dimensi kepada masalah dua dimensi. Ini boleh memperbaiki masa perkomputeran dan tidak memerlukan amaun nodul dan elemen yang banyak semasa simulasi dijalankan. Hasil daripada simulasi dan perhitungan menggunakan persamaan Lamé menunjukkan bahawa diameter tiub akan bertambah dan panjang tiub akan berkurang selepas proses pengembangan. Kesimpulan ini menepati teori dan aplikasinya dalam penggerudian dan pelengkapan telaga minyak.

TABLE OF CONTENTS

REPORT SUBMISSION FORM

APPROVAL SHEET

TITLE PAGE

DEDICATION ii

ACKNOWLEDGEMENT iii

ABSTRACT iv

ABSTRAK v

TABLE OF CONTENTS vi

LIST OF FIGURES x

LIST OF TABLES xv

CHAPTER 1 INTRODUCTION

1.0 Introduction 1

1.1 Problem Statement 1

1.2 Project Objectives 2

CHAPTER 2 LITERATURE REVIEW

2.0 Introduction	3
2.1 Casing for Well Drilling and Completion	3
2.2 Purpose of Casing	6
2.3 Types of Casing	6
2.3.1 Casing Pipe	6
2.3.2 Conductor Pipe	7
2.3.3 Surface Casing	8
2.3.4 Intermediate Casing	9
2.3.5 Production Casing	10
2.4 Casing Design	11
2.5 Solid Expandable Tubular	12
2.6 Advantages of Solid Expandable Tubular	
(Comparison to Regular Casing)	14
2.6.1 Solid Expandable Tubular for	
Constructing Extended-Reach Wells	14
2.6.2 Tubular Connections	15
2.7 Summary	16

CHAPTER 3 METHODOLOGY

3.0 Introduction	17
3.1 Simulation, Finite Element Modelling and Analysis Using ANSYS	18
3.1.1 Steps Involve In Finite Element Analysis	20

3.1.1.1 Preliminary Decisions	20
3.1.1.2 Preprocessing	21
3.1.1.3 Solution	25
3.1.1.3.1 Displacement Constraints	26
3.1.1.3.2 Concentrated Loads (Forces)	27
3.1.1.3.3 Obtain a Solution	28
3.1.1.4 Post Processing	29
3.2 Verification using Mathematical Calculation (Analytical Solution)	30
3.3 Prototype Model	32
3.4 Summary	32

CHAPTER 4 RESULT AND DISCUSSION

4.0 Introduction	33
4.1 Design and Prototype	33
4.2 Finite Element Analysis of Stress Distribution across the Wall Thickness and Verification Using Lamé's Equation	44
4.2.1 Steel	44
4.2.2 Brass	49
4.2.3 Bronze	54
4.2.4 Cast Iron	59
4.2.5 Copper	64

4.2.6 Nickel	69
4.2.7 Titanium Alloys	74
4.2.8 Tungsten	79
4.3 Summary of the Finite Element Analysis and Calculation Results	83
4.4 Solid Expandable Tubular Design	88
4.5 Discussion	88
4.6 Summary	
 CHAPTER 5 CONCLUSION AND RECOMMENDATION	
5.1 Conclusion	92
5.2 Recommendation	94
 REFERENCE	95
 APPENDIX	97

LIST OF FIGURES

Figure 2.1	Drilling, casing and cementing.	5
Figure 2.2	Cassion Pipe/ Conductor Pipe	7
Figure 2.3	Surface Casing	8
Figure 2.4	Intermediate Casing	9
Figure 2.5	Production Casing	10
Figure 3.1	Finite element model of a tubular joint.	19
Figure 3.2	Steel Tubular Which Used to model Solid Expandable Tubular for Finite Element Analysis	22
Figure 3.3	A Cross Section of Solid Expandable Tubular	23
Figure 3.4	Symmetry Modelling was used and One Quadrant Tubular was analyzed	23
Figure 3.5	Axisymmetric Model after Meshing Process	24
Figure 3.6	3D Model after Meshing Process	25
Figure 3.7	Boundary Conditions Applied to Prevent Rigid Body Motion in Y Direction	26
Figure 3.8	Solid Expandable Tubular Internal Pressure	27
Figure 3.9	Solution Obtained	28
Figure 3.10	Post Processing Shows Deformed and Undeformed Shape	29
Figure 4.1	Cross Section of Solid Expandable Tubular	34
Figure 4.2	Lower Part of Solid Expandable Tubular Cross Section	35

Figure 4.3	Upper Part of Solid Expandable Tubular Cross Section	35
Figure 4.4	Mandrel of Solid Expandable Tubular	36
Figure 4.5	Early Expansion Mandrel Used to Expand Solid Expandable Tubular	36
Figure 4.6	Inner String	37
Figure 4.7	Differential Pressure Pumped Through the Inner String	38
Figure 4.8	Stress/Strain Curve for Solid Expandable Tubular	39
Figure 4.9	Launcher	40
Figure 4.10	Solid Expandable Tubular (After Assembly All the Parts)	41
Figure 4.11	Prototype of Solid Expandable Tubular	41
Figure 4.12	Prototype of Solid Expandable Tubular	42
Figure 4.13	Engineering Drawing of Solid Expandable Tubular Prototype	42
Figure 4.14	Solid Expandable Tubular Process Sequence	43
Figure 4.15	Deformed and Undeformed Shape of Steel Expandable Tubular	45
Figure 4.16	Change in Radius of Steel Expandable Tubular	46
Figure 4.17	Change in Tubular Length of Steel Expandable Tubular	46
Figure 4.18	Radial Stress, S_x of Steel Expandable Tubular	47
Figure 4.19	Axial Stress, S_y of Steel Expandable Tubular	47
Figure 4.20	Circumferential (Hoop) Stress, S_z of Steel Expandable Tubular	48

Figure 4.21	Deformed and Undeformed Shape of Brass Expandable Tubular	50
Figure 4.22	Change in Radius of Brass Expandable Tubular	50
Figure 4.23	Change in Tubular Length of Brass Expandable Tubular	51
Figure 4.24	Radial Stress of Brass Expandable Tubular	51
Figure 4.25	Axial Stress of Brass Expandable Tubular	52
Figure 4.26	Hoop Stress of Brass Expandable Tubular	52
Figure 4.27	Deformed and Undeformed Shape of Bronze Expandable Tubular	55
Figure 4.28	Change in Radius of Bronze Expandable Tubular	55
Figure 4.29	Change in Tubular Length of Bronze Expandable Tubular	56
Figure 4.30	Radial Stress of Bronze Expandable Tubular	56
Figure 4.31	Axial Stress of Bronze Expandable Tubular	57
Figure 4.32	Hoop Stress of Bronze Expandable Tubular	57
Figure 4.33	Deformed and Undeformed Shape of Cast Iron Expandable Tubular	60
Figure 4.34	Change in Radius of Cast Iron Expandable Tubular	60
Figure 4.35	Change in Tubular Length of Cast Iron Expandable Tubular	61
Figure 4.36	Radial Stress of Cast Iron Expandable Tubular	61
Figure 4.37	Axial Stress of Cast Iron Expandable Tubular	62
Figure 4.38	Hoop Stress of Cast Iron Expandable Tubular	62

Figure 4.39	Deformed and Undeformed Shape of Copper Expandable Tubular	65
Figure 4.40	Change in Radius of Copper Expandable Tubular	65
Figure 4.41	Change in Tubular Length of Copper Expandable Tubular	66
Figure 4.42	Radial Stress of Copper Expandable Tubular	66
Figure 4.43	Axial Stress of Copper Expandable Tubular	67
Figure 4.44	Hoop Stress of Copper Expandable Tubular	67
Figure 4.45	Deformed and Undeformed Shape of Nickel Expandable Tubular	70
Figure 4.46	Change in Radius of Nickel Expandable Tubular	70
Figure 4.47	Change in Tubular Length of Nickel Expandable Tubular	71
Figure 4.48	Radial Stress of Nickel Expandable Tubular	71
Figure 4.49	Axial Stress of Nickel Expandable Tubular	72
Figure 4.50	Hoop Stress of Nickel Expandable Tubular	72
Figure 4.51	Deformed and Undeformed Shape of Titanium Alloys Expandable Tubular	75
Figure 4.52	Change in Radius of Titanium Alloys Expandable Tubular	75
Figure 4.53	Change in Tubular Length of Titanium Alloys Expandable Tubular	76
Figure 4.54	Radial Stress of Titanium Alloys Expandable Tubular	76
Figure 4.55	Axial Stress of Titanium Alloys Expandable Tubular	77
Figure 4.56	Hoop Stress of Titanium Alloys Expandable Tubular	77

Figure 4.57	Deformed and Undeformed Shape of Tungsten Expandable Tubular	80
Figure 4.58	Change in Radius of Tungsten Expandable Tubular	80
Figure 4.59	Change in Tubular Length of Tungsten Expandable Tubular	81
Figure 4.60	Radial Stress of Tungsten Expandable Tubular	81
Figure 4.61	Axial Stress of Tungsten Expandable Tubular	81
Figure 4.62	Hoop Stress of Tungsten Expandable Tubular	81

LIST OF TABLES

Table 2.1	Steel costs represent well casing cost.	12
Table 3.1	Mechanical Properties of Materials (SI Units)	21
Table 4.1	Summary Results Obtained From Finite Element Analysis via ANSYS	84
Table 4.2	Summary of Results Obtained from Calculation via Lamé's Equation	85
Table 4.3	Comparison between Finite Element Analysis Results with Theoretical Values (Discrepancy in %)	87

CHAPTER 1

INTRODUCTION

1.0 Introduction

This project begins with recognising the fundamental aspects of casing design. Literature review about casing design and solid expandable tubular were carried out to gain more understanding. This project studied the solid expandable technology as the casing design in order to improve drilling time and cost optimisation. The outcome from this study was the simulation results that were performed using ANSYS. The results were compared with calculation (mathematical method). Finally, this project will produce a model via rapid prototyping from the drawing of conventional casing and solid expandable tubular by CATIA.

1.1 Problem Statement

Casing design has followed an evolutionary trend and most improvements have been made due to the advancement of technology. Maximising hole conservation while optimizing well economics in both conventional and deepwater wells is a continual challenge. Contributions to the technology in casing design have come from fundamental research and field tests, which made casing safe and economical.

When reaching the target on time and reducing drilling costs are always difficult to achieve, this project provides the means to show that can happen with Solid Expandable Tubular (SET) Technology. This technology essentially changes

how the main load-carrying member around which all well designs are built, namely, the casing, is installed.

1.2 Projects Objectives

The first objective is to study the technology in solving problems regarding casing. For this project, solid expandable tubular is the design which has been chosen for this matter. Solid expandable tubular is a casing that can expand and enables operators to reach the total depth with a larger hole than with a conventional casing design. The research will be carried out to study the expansion system mechanism of solid expandable tubular.

The second objective is to design a solid expandable tubular and its mechanism of expansion by CATIA. This will then be used to produce a model via rapid prototyping.

The third objective is to perform the simulation (finite element modelling) using finite element software, ANSYS for solid expandable tubular. The finite element modelling and analysis is aim at studying the effect of material properties on the stresses in solid expandable tubular wall and the change in its radius due to pressure.

The fourth objective is to do the mathematical calculation (analytical solution) to compare and verify the result from finite element modelling and analysis. This will then be used to design the solid expandable tubular using the theories of failure.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

As the search for commercial hydrocarbon deposits reaches greater depths, the number and sizes of the casing strings required to drill and to complete a well successfully also increases. By choosing the correct size, type, and amount of casing that is used in well construction is of utmost importance to the success of the well. The casing must be of sufficient size and strength to allow the target formations to be reached and produced. Thus, an important responsibility of the well engineer is to design the casing program that will allow the well to be drilled and operated safely throughout its life. The cost savings can be achieved through an optimal design, as well as avoid the risk of failure from an improper design.

2.1 Casing for Well Drilling and Completion

Casing for well drilling is a large-diameter pipe lowered into an open hole and cemented in place. The well designer must design casing to withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive brines. Most casing joints are fabricated with male threads on each end, and a short-length casing couplings with female threads are used to join the individual joints of casing together, or joints of casing may be fabricated with male threads on one end and female threads on the other. Casing is run to protect fresh-

water formations, isolate a zone of lost returns or isolate formations with significantly different pressure gradients. The operation during which the casing is put into the well bore is commonly called "running pipe." Casing is usually manufactured from plain carbon steel that is heat-treated to varying strengths, but may be specially fabricated of stainless steel, aluminum, titanium, fiberglass and other materials [1].

Casing for well completions is a steel pipe cemented in place during the construction process to stabilize the wellbore as shown in Figure 2.1. The casing forms a major structural component of the wellbore and serves several important functions: preventing the formation wall from caving into the wellbore, isolating the different formations to prevent the flow or crossflow of formation fluids, and providing a means of maintaining control of formation fluids and pressure as the well is drilled. The casing string provides a means of securing surface pressure control equipment and down hole production equipment, such as the drilling blowout preventer (BOP) or production packer. Casing is available in a range of sizes and material grades [1].

Drilling and Casing

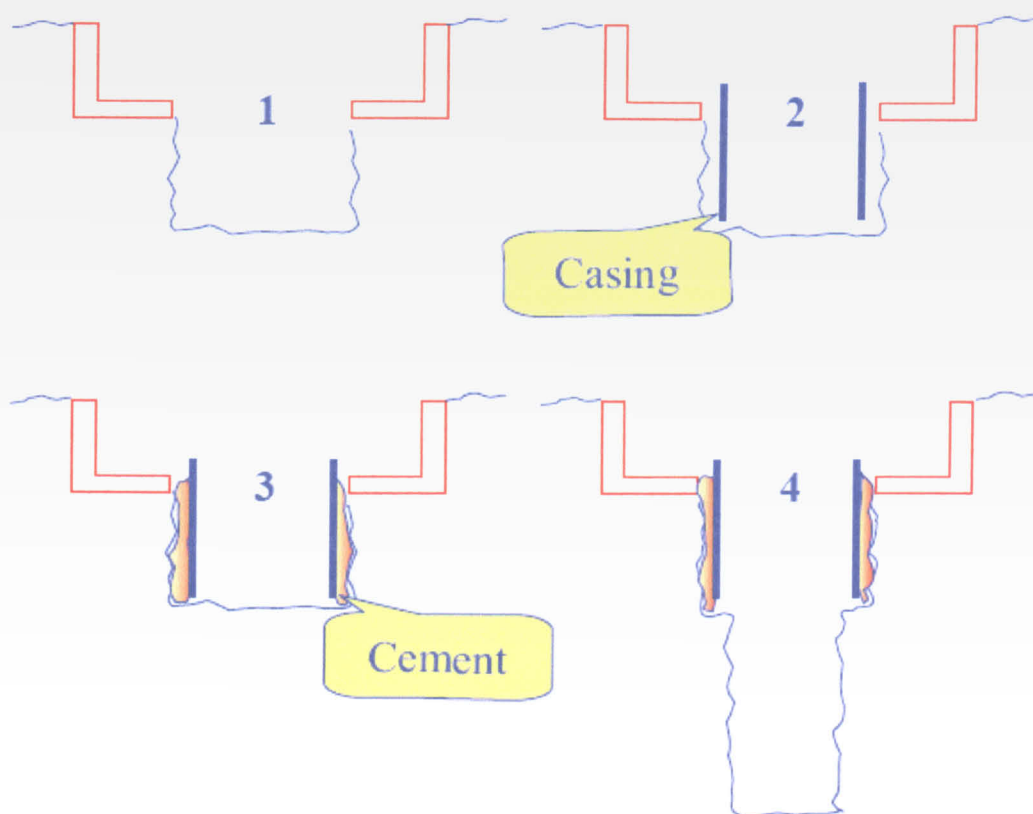


Figure 2.1 Drilling, casing and cementing.

2.2 Purpose of Casing

The main functions of the casing in any well are to maintain hole integrity, isolate abnormally pressured zones, protect shallow weak formations from heavier mud weights required in the deeper portions of the hole, prevent release of fluids from any stratum through the well bore (directly or indirectly) into the waters, prevent communication between separate hydrocarbon-bearing strata (except such strata approved for commingling) and between hydrocarbon and water-bearing strata, prevent contamination of freshwater-bearing strata, support unconsolidated sediments, provide a means of controlling formation pressures and fluids, and to isolate fresh water, salt and coal seams.

2.3 Types of Casing

There are primary five types of casings that are commonly used in well construction. There are cassion pipe, conductor pipe, surface casing, intermediate casing and production casing. These types of casing are discussed in subsequent section.

2.3.1 Cassion Pipe

Other names for this casing are Drive pipe or Stove pipe. Surface formations are lose and consolidated. They consist mainly of sand and stones. Due to this the surface hole will need to be cased off before any drilling can take place as shown in

Figure 2.2. Large heavy walled pipe is often driven to a point of refusal or a safe depth. This case can say to be often and may not always be the case.

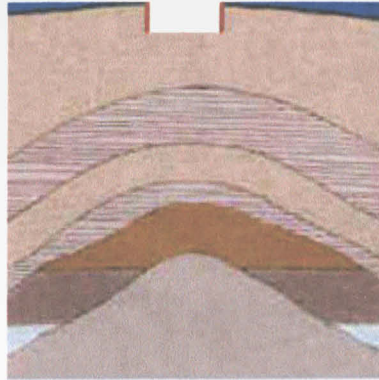


Figure 2.2 Cassion Pipe/ Conductor Pipe

2.3.2 Conductor Pipe

The conductor pipe as shown in Figure 2.2, is the first casing to be put in place, and is generally installed before the rig arrives on location (generally as now days it has become more common for the rig to install the pipe). On land, the hole for this shallow casing is often dug with an auger drill mounted on a truck, or driven using a diesel or steam hammer. Such casing can be driven to 250 feet. Conductor casing measuring between 16 to 24" outside diameter is used onshore, and between 24 to 48" for offshore. However the size of this casing will depend on the depth of the hole, the deeper the hole the larger the casing. [2]

Such a string of pipe could be driven as deep as 450' until the fresh water zones are covered. There are many reasons for such pipe, include, to return drilling fluid and cutting back to surface and clean the hole, to protect fresh water sands, to

stop washouts under the drilling rig, to give a base and support for the next string of casing and to protect the following casing string.

2.3.3 Surface Casing

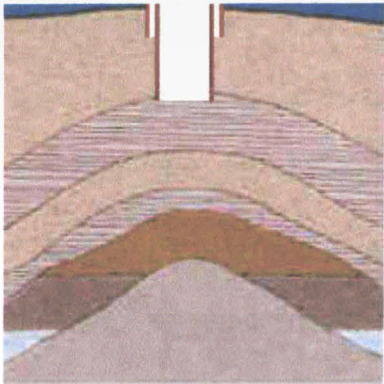


Figure 2.3 Surface Casing

Surface casing as shown in Figure 2.3, is set to protect water sands, case unconsolidated formations, provide primary well control, and support other casing and case off lost circulation zones. Such a string would be run and cemented back to surface. It is normally the first casing to support some for of secondary well control equipment. Drilling this hole section is normally fast and little time is wasted. In some area a pilot hole may be drilled then opened up to a larger size.

2.3.4 Intermediate Casing

The intermediate casing is the hardest casing to run in the hole among all the casing run. Prolonged drilling can and often will damage it. Corrosion is common as such a string will often cover salt zones. The justification for this string is to cover many of the problem zones that are encountered in the top sections of the hole such as lost circulation and water flows. Such zone need to be isolated as the drilling fluid weight may have to be raise in the deeper section of the hole. It will also be use too supports the completion and any other string that may be ran later. The casing point "where the shoe is to be set" must be in a firm and solid formation as the secondary well control equipment will be installed on top. A leak off or integrity test will be carried out to test the shoe. It is often run to depths of 5 or 6000 ft. and would normally cemented back to surface. This string will often be the largest cement job and could be done in two stages. Figure 2.4 shows the intermediate casing.

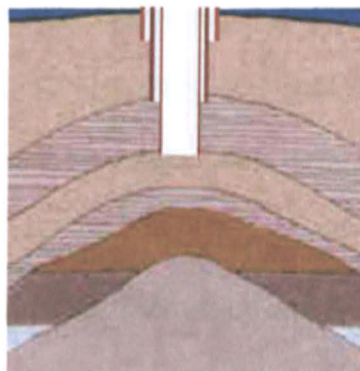


Figure 2.4 Intermediate Casing