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"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Material & structures)"

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STRESS-STRAIN AND FAILURE ANALYSES OF STEEL PIPE WITH STRESS CONCENTRATION FACTORS (SCFs) UNDER STATIC 3 AND 4 POINT BEND CONDITIONS

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotation which have been duly acknowledged."

Signature : ……………………………

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Date : ……………………………

Specially dedicated

To my beloved family and friends

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ABSTRAK

Sistem dan struktur-struktur paip digunakan dengan meluas dalam banyak industri. Tiub dan paip digunakan terutamanya dalam bidang stuktur. Oleh itu, tekanan memainkan kriteria penting pada paip tersebut. Tetapi, kekuatan paip selalu dikira dengan menganggap paip tersebut dalam keadaan sempurna. Malah, semua paip mangandungi retak kecil yang bertindak sebagai penubuh tekanan atau penumbuan tegasan. Selain daripada retak kecil, lubang yang berlainan bentuk juga dihasilkan dengan sengaja pada paip demi kegunaannya. Penumbuan tekanan akan mengurangkan kekuatan asal sebatang paip. Penumbuan tekanan ini boleh dikirakan dengan faktor penumbuan tekanan, K. Faktor penumbuan tekanan bermaksud nisbah takanan maksima kepada tekanan nominal. Dengan itu, ujian lenturan digunakan untuk memastikan paip mempunyai kemuluran dan kekuatan yang cukup untuk menahan lenturan tanpa gagal. Tekanan lenturan berlaku apabila satu komponen itu dikenakan degan daya yang sebalik dari bercuba menghulurkan atau mengecut komponen tersebut. Ini akan menghasilkan gabungan daripada tekanan tegangan dan mampatan. Terdapt dua jenis ujian lenturan iaitu ujian liku tiga mata dan liku empat mata. Dalam laporan ini, paip keluli dianalisiskan dengan faktor penumbuan tekanan (SCFs) yang berlainan iaitu lubang bulat dan slot dengan kedua-dua ujian tersebut. Kedua-dua spesimen tersebut didilampirkan dengan lapan tolok terikan pada lokasi yang tertentu dari dekat ke jauh daripada penumbuan tekanan yang dihasilkan. Tolok terikan ini disambung kepada logger data untuk mendapatkan keputusan apabila tekanan dikenakan pada spesimen dengan mengunakan mesin ujian sejangat. Graf terikan terhadap jarak tolok terikan dari penubuh tekanan dilukis berasakan keputusan yang terdapat dan mengirakan faktor penumbuan tekanan secara eksperimen. Selain itu, faktor penumbuan tekanan juga dikirakan secara teori dan dibandingkan. Daripada keputusan projek ini, ditunjukkan dengan jelas bahawa bentuk yang berlainan akan mempunyai nilai faktor penumbuan tekanan yang berlainan. Tetapi, kedua-dua spesimen lubang bulat dan slot menujukkan bahawa

apabila menjauhi dari penubuh tekanan, terikan akan berkurang. Selain itu, terikan adalah berkadar terus dengan daya yang dikenakan. Daya yang tinggi akan menghasilkan terikan yang tinggi.

ABSTRACT

Piping system and structures are widely used in many industries. Tube and pipe are mainly use in structural application. So, stress plays an important criterion on these pipes. But the strength of the pipes usually calculated by assumed the pipes are perfect. In fact, all pipes contain small cracks that act as stress raisers or stress concentration. Besides small cracks, some holes of different shape also purposely produced for its uses. Stress concentration will reduce the strength of the pipe. The stress concentration is measured by stress concentration factor, K. Stress concentration factor is defines as the ratio of the maximum stress to nominal stress. So, bending tests are carried out to ensure that the pipe has a sufficient ductility and strength to stand bending without fracture. Bending stress occurs when a component is loaded by force which instead of trying to stretch or shrink the component. It will generate a combination of tensile and compressive stress in the load-carrying components. There are two types of bending tests, which are three-point bend and four-point bend tests. In this report, steel pipes are analyzed with different types of stress concentration factors (SCFs) which are circular hole and slot under both bending tests. Each specimen was attached with eight strain gauges on desired location from near to far from the stress raisers. These strain gauges are connected to the data logger to take the reading when the load is applied by the universal testing machine. Graphs of strain against distance of the strain gauges from the stress raisers were plotted based on the data recorded to calculate the experimental stress concentration factor. Besides, the theoretical stress concentration factor also calculated by using analytical method. Both theoretical and experimental results were compared for validation. From the results, it is clearly shown that different shapes will have the different value of the stress concentration factor. But both circular hole and slot specimens showed that the strain will decrease as the distance from the stress raisers is increase. Besides, the strain is directly proportional to the applied load. Higher loads will contribute higher strain.

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LIST OF SYMBOLS

σ_w	=	working stress
σ_0	=	yield strength
σ_u	=	tensile strength
N_0	=	factor of safety based on yield strength
N_u	=	factor of safety based on tensile strength
σ_{max}	=	Maximum stress
σ_{nom}	=	Nominal stress
P	=	Total Load
H	=	Height
h	=	Notch height
K_{tg}	=	Gross stress concentration factor
K_{tn}	=	Net stress concentration factor
K_e	=	Experimental stress concentration factor
E	=	Modulus of elasticity
I	=	Moment of inertia
L	=	Span length of bending member
M	=	Maximum bending moment
A_g	=	Gross sectional area

LIST OF ABBREVIATIONS

SCFS	=	Stress Concentration Factors
FEM	=	Finite Element Method

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

A pipe or tube is a tubular section or hollow cylinder. It is usually, but not necessarily of circular cross-section. It is mainly used to convey substances which can flow such as liquid and gas (fluids), slurries, powder, masses of small solids. Besides, it also can be used for structural applications such as for trusses, offshore structures and aerospace members where weight reduction is a prime concerned. This is because hollow pipe is far stronger per unit weight than solid members. With the same diameter and the same material, a solid rod is stronger than a hollow pipe. However, with the same weight and material, the hollow pipe is stronger than a solid rod. Because a hollow pipe is lighter than a solid rod for the same outside diameter and the hollow pipe would have a larger diameter in order to match weights with the solid rod and a larger diameter rod or pipe is stronger than a smaller diameter one.

Pipe or tube is generally specified by a nominal diameter with a constant outside diameter (OD and the thickness) according to a certain standard. It generally manufactured to one or several international or national industry standards. While similar standards exist for specific industry tubing, tube is often made to custom sizes and a broader range of diameters and tolerances. Many industrial and government standards exist for the production of pipe and tubing.

Bending tests are carried out to ensure that a metal pipe or tube has a sufficient ductility and strength to stand bending without failure. Bending stress occurs when a component is loaded by force which, also trying to stretch or shrink the component. Those bending forces generate a combination of tensile and compressive stresses in the load-carrying components, known as bending stresses. In bending tests, the load is applied vertically or transversely at either one or two points. As a result, these tests are referred to as three-point and four point bending, respectively.

In this project, steel pipe or tube contained stress concentration factors (SCFs) was studied or analyzed. Stress concentration factor is defined as the ratio of the greatest stress in the area of a notch or other stress raiser to the corresponding nominal stress. It is a theoretical indication of the effect of stress concentrators on mechanical behavior. Stress concentration factor usually is higher than the empirical fatigue notch factor or strength reduction ratio, because it does not take into account stress relief due to local plastic deformation. The examples of shapes or discontinuities that cause these stress concentrations are cracks, sharp corners, holes, and, changes in the cross-section area of the object.

1.2 Problem Statement

An object is strongest when force that applied on it is evenly distributed over its area, so a reduction in area for example caused by stress raisers, will results in a localized increase in stress. A material can fail, via a propagating crack, when a concentrated stress exceeds the material's fracture strength. The real fracture strength of a material is always lower than the theoretical value because most of the materials contain stress raisers that cause stress concentrations. Failures always start at stress concentration areas, so removing such defects will increase the fatigue strength of the structures or components. To prevent the materials fail, the real stress-strain distributions should be investigated with different stress concentration factors (SCFs) which subjected to static 3 and 4 point bend loads.

1.3 Objective

The objective of this project is to investigate and define stress-strain distributions and failure analysis of steel pipe or tube with different stress concentration factors (SCFs) subjected to static 3 and 4 point bend loads.

1.4 Scope

The scopes of this project involve the following:

- Conduct the literature study on stress-strain and failure analysis of structure in general. This includes the effect of different type of stress concentration factors (SCFs) such as circular or elliptical holes and notches.
- Design the test specimens from the steel tube that contains the proposed SCFs.
- Determination of theoretical SCFs (k_t) by using analytical or Finite Element (FE) method.
- By using the strain gages, measure the strains at selected and critical locations to investigate and validate the theoretical analysis and predictions.
- The use of finite element (FE) method may also be considered to verify or validate the measured and analytical stress-strain data.
- Define the actual failure stress / collapsed load of the proposed design by conducting the real 3 and 4 bend until the specimen fail.

CHAPTER 2

LITERATURE REVIEW

2.1 What constitutes failure?

Structural members and machine elements can fail to perform their intended functions in three general ways:

i. Excessive elastic deformation
ii. Yielding, or excessive plastic deformation
iii. Fracture

i.

An understanding of the common types of failure is important in good design because it is always necessary to relate the loads and dimensions of the member to some significant material parameters which limits the load-carrying capacity of the member.

2.1.1 Excessive elastic deformation

Two general types of excessive elastic deformation may occur: (1) excessive deflection under condition of stable equilibrium, such as the deflection of beam under gradually applied loads; (2) sudden deflection, or buckling, under conditions of unstable equilibrium.

Excessive elastic deformation of a machine part can mean failure of the machine just as much as if the part completely fractured. For example, a shaft which is too flexible can cause rapid wear of bearing, or the excessive deflection of closely mating parts can result in interference and damage to the parts. The sudden buckling type of failure may occur in a slender column when the axial load exceeds the Euler critical load or when the external pressure acting against a thin-walled shell exceeds a critical value. Failures due to excessive elastic deformation are controlled by the modulus of elasticity, not by the strength of the material. Generally, little metallurgical control can be exercised over the elastic modulus. The most effective way to increase the stiffness of a member is usually by charging its shape and increasing the dimensions of its cross section.

2.1.2 Yielding, or excessive plastic deformation

Yielding, or excessive plastic deformation, occurs when the elastic limit of the metal has been exceeded. Yielding produces permanent change of shape, which may prevent the part from functioning properly any longer. In a ductile metal under conditions of static loading at room temperature yielding rarely results in fracture, because the metal strain hardens as it deforms, and an increased stress is required to produce further deformation. Failure by excessive plastic deformation is controlled by the yield strength of the metal for a uniaxial condition of loading. For more complex loading conditions the yield strength is still significant parameter, but it must be used with a suitable failure criterion. At temperatures significantly greater than room temperature metals no longer exhibit strain hardening. Instead, metals can continuously deform at constant stress in a time-dependent yielding known as creep. The failure criterion under creep conditions is complicated by the fact that stress is not proportional to strain and the further fact that the mechanical properties of the material may change appreciably during service.