UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# Faculty of Mechanical Engineering

# INVESTIGATION OF ON-STREAM PIPE REPAIRING FOR OIL AND GAS APPLICATIONS

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# INVESTIGATION OF ON-STREAM PIPE REPAIRING FOR OIL AND GAS APPLICATIONS

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**A thesis submitted**
**in fulfilment of the requirements for the degree of Master of Engineering in Mechanical Engineering**

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## DECLARATION

I declare that this project entitled "Investigation of On-Stream Pipe Repairing for Oil and Gas Applications" is the result of my own research except as cited in the references. The project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## APPROVAL

I hereby declare that I have read this project and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Engineering Mechanical (Energy Engineering).

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## DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this project and on His wings only have I soared. I also would like to present my work to those who did not stop their daily support since I was born, I can not thank you enough for all you have offered me. My dear father May Allah protect you and protect you and prolong your life and my beloved mother God have mercy on her. They never hesitate to provide me with all the facilities to push me foreword as much as they can. This work is a simple and humble reply to their much goodness I have taken over during that time. Thank you for giving me a chance and I love them.

I also dedicate this project to my friends and my wife who has supported me through my life. I always miss and I cherish the memories that we had. God bless you.

*FARHAT GIUMA ALI GIUMA*

## ABSTRACT

Leakage of pipelines in refinery plants is a major issue that can affect the plant efficiency and safety. Pipelines leak can be caused by many factors. One of the most common factors is pipe corrosion that results to the pipe thinning. In some extend, consistent vibration of the pipe can also lead to crack, which consequently result to leakages. Minor leaks can be sealed without shutting down the units. There are ways to repair piping leaks on stream as specified by American Petroleum Institute (API) 570 Piping Inspection Code. The leaks can be repaired on stream either by using full encirclement welded split sleeve enclosure, fillet welding or patches insertion. Both methods are categorized as temporary welding repairs. Alternatively, a specifically designed bolted clamp can be installed to seal the leak temporarily before permanent repair is performed. In this study, a feasibility study was performed to examine temporary pipe crack repair. A mock up testing rig that represent the actual on-site condition was developed. Fillet welding and patch insertion were performed on the stainless-steel pipe (Schedule 10). Burn through marks and maximum inner surface temperature of the pipe was examined. Finite Element Analysis (FEA) was also performed to provide supportive temperature data of the repair process. The results suggest that fillet welding is too risky to be performed on-stream as the inner surface temperature is way passing the product auto-ignite temperature.

## *ABSTRAK*

*Kebocoran saluran paip di kilang penapisan minyak merupakan satu isu besar dan kritikal. Perkara ini boleh menyebabkan kilang penapisan ditutup sementara yang akan menyebabkan kecekapan dan tahap keselamatan pekerjaan terjejas. Kebocoran saluran paip lazimnya disebabkan oleh penipisan paip akibat daripada tindak balas kimia antara hidrokarbon paip keluli. Getaran melampau juga boleh menyumbang kepada keretakan paip keluli dan akhirnya kebocoran boleh berlaku. Beberapa langkah boleh diambil untuk pembaikan kebocoran secara langsung tanpa penutupan sistem. Piawaian yang ditetapkan untuk diikut adalah daripada American Petroleum Institute (API) 570. Kebocoran dapat dibaiki secara langsung dengan memasang penutup sarung pemisah kimpalan, kimpalan kambi ataupun tampalan. Langkah pembaikan ini merupakan langkah sementara sebelum langkah pembaikan kekal diambil. Selain daripada itu, pengapit bolt boleh dipasang di kawasan retakan sebagai langkah sementara. Pengapit ini direka khas untuk menampung daya tekanan di paip keluli. Di dalam projek ini, satu kajian keberkesanan telah dilalukan untuk melihat kembali langkah sementara pembaikan keluli paip. Kimpalan kambi dan tampalan dipasang di paip yang bocor secara eksperimen. Analisis unsur terhingga menggunakan perisian ANSYS juga dilakukan untuk mendapatkan data awalan sebagai data sokongan. Dapatan menunjukkan kimpalan kambi amat berisiko untuk dilakukan dengan ketebalan sedia ada. Suhu didapati terlalu tinggi dan boleh menyebabkan kebakaran.*

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

This chapter aims to present a brief overview of this research on the Investigation of On-Stream Pipe Repairing for Oil and Gas Applications case study. This chapter will provide a background to the research, research overview, research problem and identify the research objectives. Then, the overview of the contents of each chapter in this thesis is presented. Failure analysis is a critical component in engineering feasibility studies. Important clues are discovered throughout the investigation that provides insight into what may have caused the failure and what contributing factors may have been involved. The failure analyst is aided by a broad knowledge of materials in general. This chapter will also present the significance of the research.

## 1.2 Background of Research

Pipelines are among the safest and most efficient methods of transporting oil and natural gas across long distances (Islam, 2013). Over 1.7 million kilometres of oil transmission pipelines exist worldwide and over 60% of these pipelines have been in service for over 40 years (Mohitpour, 2007) and (Chapetti, 2001). Many of these pipelines are subjected to external corrosive environments, such as saltwater, sulphur ingress media, or groundwater, which can cause stress corrosion cracking and wall loss (Islam, 2013) and (Ossai, *et al.* 2015). Traditionally, sections of steel pipelines with corrosion damage are either removed and completely replaced or reinforced with a two-part steel sleeve. These traditional repairs can be expensive, dangerous, and difficult to install in underground piping systems as well as close-spaced pipe racks in the plan (Bai and Bai. 2014). This study proposed to investigate the repairing methods of oil and gas pipelines on-stream location and provide different case studies and its pros and cons in term of analysing and provide advising to achieve the objective of pipeline repairing. There are several codes and international standard need to be followed to compare this study and must be listed down to show the difference between work done and required standard. Flowing the method of repairing to ensure the smooth and uninterrupted flow of oil and gas to the end-users, it is imperative for the field operators, pipeline engineers, and designers to be corrosion conscious as the lines and their component fittings would undergo material degradations due to corrosion. Besides, owing to the findings of new locations for crude oil and natural gas, the need for high strength materials that can be used for pipes and their joining has gained paramount importance.

Pipes have to bear internal fluid pressure in addition to the adverse external conditions. Welding of high strength pipeline materials is also a challenge for engineers in the construction of pipes as well as oil and gas transportation lines. To increase reliability and profitability in this industry, effective welding techniques are needed for these materials. To understand the issues related to the welding of these high strength steels, requirements of chemical composition and mechanical properties for these materials will be discussed in detail of this report. Inspection and operation un-stabilities may detect a deficiency in a pipeline. The general inspections are normally the visual methods, while other inspections are required which can be done by different methods that are normally known as NDT inspections. The variety of damage may be covered the range of insignificant to a fully buckled or parted pipeline as shown in the following list which can detect the damage of the pipeline during the inspection and mapping;

- Mechanical damage to the pipe.
- Buckled pip.
- Lateral and axial movement.
- Leaks.
- Seedbed condition.
- Free spans.
- Corrosion (external, internal).
- Damage in coating, insulation, field joints.
- Anode consumption or detaching.

## 1.3 Overview of Research

Several welding repair methods are currently available for cross-country pipelines, tanks and vessels. Examples of these methods are hot tapping and sleeve-repairs that repair the pipeline externally while in-service (Wendell, 1982). Other repair methods would require the service to shut down and the fluid to be evacuated Bruce, (Bruce, 2004).

However, to prevent pipeline corrosion and flaw-related rupture, the area associated with the corrosion or flaw damages must be reinforced and/or repaired. Other defects of pipelines that require repair include internal corrosion, construction flaws, service induced cracking, and mechanical damage. Defects oriented in the longitudinal direction of the pipeline tend to cause the pipeline to fail by the fluid-applied hoop stress (due to pressure loading) and must be reinforced in the circumferential direction. Defects oriented in the circumferential direction of the pipeline tend to cause the pipeline to fail from axial stresses. Reinforcement in the longitudinal direction must then be applied (API, 1991). The installation of welded full-encirclement steel repair sleeves is the most commonly used method for repairing pipelines (API, 1985) and (Bruce, 2005). These sleeves help in resisting hoop stress and if the ends are welded circumferentially to the pipeline axial stresses will be resisted.

Some external repair methods are typically performed while the pipeline remains in service, such as hot tapping (Wendell, 1982). Pipeline repair by weld deposition directly over a flaw or defect is an existing technology that can be applied directly to the area of wall loss (i.e. external repair of an external wall loss) or the opposite side to the wall loss (i.e. external repair of an internal wall loss) (Bruce, 2005). Applying these repair methods to the inside of an out-of-service pipeline has no apparent technical limitations. Current application of these repair methods to the inside wall surface of a pipeline, however, would require that the hydrocarbon or gas be removed from the welding environment.

## 1.4 Problem Statement

In this research, a numerical model is established to examine the heat distribution on the pipe surface with a certain heat input applied. The results obtained are utilized to evaluate whether hot tapping for on-stream pipe repairing is feasible or not for the given pipe and crack criteria. Section 8 in American Petroleum Institute (API) 570 has mentioned the method to repair, alter and rerating the pipe systems in oil and gas industries. Apart from that, API 570 also covers the inspection, repair, alteration, and rerating procedures for metallic piping systems that have been in-service. However, in some conditions, the given code of standard has no information on whether a suggested method is accepted or not. Thus, in this research work, numerical model was established to provide the supportive data whether the suggested method is feasible or not.

## 1.5 Objectives of Research

The objectives of this research are as follows:

a) To establish a numerical model to simulate stream pipe welding based on standard codes.

b) To perform numerical simulations using the established numerical model.

## 1.6 Scope of Research

In this project, a feasibility study was performed to examine the method to temporarily on stream repair pipe crack. A mock-up testing rig that represents the actual on-site condition was developed. Fillet welding and patch insertion were performed on the stainless-steel pipe (Schedule 10). Burn through marks and maximum inner surface temperature of the pipe was examined. Finite Element Analysis (FEA) using ANSYS R16.1 was also performed to provide supportive temperature data of the repair process.

## 1.7 Thesis Outline

This study has organized a summary of the contents of each chapter is as follow:

- Chapter 1. describes a general idea, problem statements, and the objective of the current study. The scope of the thesis and the scope of work are described in this chapter.

- Chapter 2. illustrates literature on previous work relevant to the current research. According to the current title, it intends to present a review of the literature on the subject and to discuss the scope of this research area by investigation of on-stream pipe repairing for oil and gas applications.

- Chapter 3. presents the methodology and firstly, the research is focused on the design of the pipe. Then, weld that used in this research are model of cracking line at pipe with remaining thickness and weld for patch repair. Furthermore, this study on focuses on establishing a numerical model using ANSYS version 16.1 as a software tool for simulation of investigation of on-stream pipe repairing for oil and gas applications.

- Chapter 4. devote to data gathering and use this data to discuss the results of the current study.

- Chapter 5. concludes this study and recommends further actions and propose future study areas.

## 1.8 Summary

This chapter provides detail, information about the research background and highlighted current research problems. In this research, work wants to focus on analyzing the available methodology for the study with different parameters discussed in this study. The analysis of this study will be useful for various researchers to increase its efficiency and performance.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The literature review is a key platform for presenting and understanding current research-related previous work. Consequently, a number of information sources have been accessed to collect information on repairing pipelines. It aims to present a summary of the literature on the subject in accordance with the current title and to address the scope of this research area through investigation of On-Stream Pipe Repairing for Oil and Gas Applications. For so long, unsafe and inappropriate liquid and natural gas pipelines have been used to transport rough oil, refined petroleum products and natural gas from their specific assembly systems to facilities where they are refined, processed or stored. As with any ageing substructure next a certain period, precautionary and ongoing care is required to guarantee the sustained performance of the advantage and to prevent issues from arising which could potentially have a detrimental effect or even lead to failure. Tubes and pipelines are no dissimilar in this respect. To bring into line with federal regulations and guarantee the continued reliability of their pipeline assets, operators are obligatory to improve and implement an honesty management plan for each pipeline they operate. Integrity management of pipelines is a main worry for pipeline operators, and it requires information of the characteristics of pipelines, evaluating the threats to pipeline integrity, and planning the mitigative responses to the various threats. Operator's need trust on such knowledge to plan and execute their integrity assessment strategies. Examples of innovative tools commonly used in the oil and gas industry to stop leaks from damaged oil and gas pipelines are mechanical pressure clamps. Nevertheless, clamps are typically not recommended if leaks result from the failure of the pipeline. Therefore, it is clear that the inspection of the leaking pipeline is very critical when deciding on the repair strategy. Accordingly, the importance of oil and gas pipelines, piping codes, standards and specifications, inspection organization, inspection and maintenance of oil & gas pipelines, inspection and maintenance policies for oil & gas pipelines, repairs and alterations, summary of repair method, types of pipelines repair modes and pipelines repair techniques, welding, finite element in welding processes, pipelines repair modes, pipelines repair techniques, welding, on stream pipe repairing methods, and ANSYS associated with problems in oil and gas and brief sight to the failure analysis process are presenting.

## 2.2 Importance of Oil and Gas Pipelines

Oil and Gas pipelines mostly become a major part of mankind's concerns because of its obvious impact in facilitating the transportation of oils, water and gases. In addition, oil and gas pipeline urbanized to be indispensable and inevitable application. Broad attention was therefore paid to the application of pipelines in order to ensure the safety of oil and gas through the implementation of the inspection approach, which is the effective technical measures for the safety of oil and gas pipelines (Hua *et al*, 2019). However, due to oil and gas pipelines are exposed to natural disasters and can have a significant environmental impact, then the analyse of the probability of pipeline failure by Fuzzy Fault Tree Analysis (FFTA) is proposed by (Badida *et al*, 2019). The author's emphasised the expected result be helpful to the security of oil and gas pipeline risk management. In addition, the common and popular tragedy is the internal deterioration and fracturing of oil and gas pipelines. Numerous studies considered over mentioned phenomenon from several aspects. The study presented by (Askari *et al*, 2019), the authors discussed the mods and corrosion mechanism for general/localized metal loss and environmentally aided cracking are discussed extensively. However, they concluded that due to some failure case studies and filed history, each type of defined corrosion mechanism has been identified and verified.

The utmost encounters of CO2 transport through pipelines are related to integrity, flow assurance, capital and operating costs, and health, safety and environmental factors (Onyebuchi, *et al.*, 2018), the authors presented a review involving a systematic assessment of various challenges that delay the deployment of CO2 pipeline transport and are based on a comprehensive survey of CO2 pipeline transport.

## 2.3 Piping Codes, Standards and Specifications

It is indispensable to fulfil with industry codes, standards, and specifications for successful completion of process capability, safe operation, and the satisfaction of health, safety, and environmental (HSE) requirements especially in the new computer-aided design (Weigele *et al*, 2007).

### 2.3.1 Definitions

For process piping systems, the general demand for the design, materials, fabrication, structure, test, and inspection are established by a code. For example, a classified design code is ASME B31.4 - Pipeline Transportation Systems for Liquid Hydrocarbons and other liquids (Pérez-Suárez *et al*, 2019). For pipelines, this code is the most commonly used design code whereas ASME B31.3 - Process piping is a classified code for process plants design (ASME B31.4, 2002) and (ASME B31.3, 2001). More detailed design, construction parameters, standard dimensions and tolerance requirements for individual tube components, such as various types of valves, tubes, tees, flanges and other in-line items. Complete a pipeline/piping system are included in a standard such as ASME B16.5 - pipe flanges and flanged fittings. It is classified as a dimensional standard, but it also refers to ASTM material specification most of the time. More specific information and data on the component are given by a specification, as the word implies. The most commonly used material specifications are the ASTM specifications, although they sometimes are called standard specification. For example, ASTM A 105 is known as a standard specification for carbon steel forgings for piping applications. Even for experienced personnel, it is not uncommon to confuse the definitions of these three types of documents, and it is important to comprehend the distinct differences (Weigele *et al*, 2007) and (Mohitpour, 2005).

### 2.3.2 Standard Codes

It is typical for an organization to require compliance to code, from the basic design to mechanical completion of a pipeline. For example, the owner of the pipeline makes the contractual requirements according to ASME B31.4 to ensure safety for personnel and pipeline during construction, commissioning, and operation (Weigele *et al*, 2007). The codes, standards, and specifications that are related to pipelines, piping systems and piping components are obtainable by different organizations. These organizations have commissions comprising of delegates from industry associations, manufacturers, industry operators, government agencies, insurance companies, and other concerned parties. A commission is responsible for maintaining, updating, and revising the codes, standards, and specifications, taking into consideration all-technological expansion, research, and experience feedback from both users and operators. Changes in referenced codes, standards, specifications, or organizing are of the committee tasks as well (Weigele *et al*, 2007) and (Mohitpour, 2005). Codes for the oil and gas industry have been established for many years, and there have been few changes to these codes. Revisions are published periodically, listing amendments that have been made to any document. Engineers and designers who work regularly with the document must use the latest editions. For a specific version, issue, addendum, or revision of a code or standard, the piping/pipeline engineer must be aware of the national, state, provincial, and local laws and regulations governing its interpretation, besides to the commitment made, by the owner and the limitations described in the code or standard. The following codes are important for pipelines, piping systems and piping components of ASME B31: (1)ASME B31.1- Power Piping; (2) ASME B31.2 - Fuel Gas Piping; (3) ASME B31.3 - Process Piping; (4)ASME B31.4 - Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohol', (5) ASME B31.5 - Refrigeration Piping, (6) ASME B31.8 - Gas Transmission and Distribution Piping Systems', (7)ASME B31.8S - Managing System Integrity of Gas Pipelines', (8)ASME B31.9 - Building Services Piping; (9)ASME B 31.ll - Slurry Transportation Piping Systems; (10) B31G - Manual for Determining Remaining Strength of Corroded Pipelines; and (11)ASME B31 - Standards of Pressure Piping (ASME B31.4, 2002), (ASME B31.8, 2002) and (ASME B31.3, 2001).

### 2.3.3 Standards and Specifications

ASME B31.3 (ASME B31.4, 2002), (ASME B31.8, 2002) and (Mohitpour, Mo *et al*.2005) is the design code supported by numerous standards and specifications, that cover a great detail of information and data regarding the individual components that make up a pipeline or piping system. Pipeline components are defined as pipe, fittings, valves, gaskets,