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BOILER TUBE REMAINING LIFE ACCORDING TO LARSON-MILLER PARAMETER

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DECLARATION

I declare that this thesis entitled "Boiler Tube Remaining Life According to Larson-Millar Parameter" is the result of my own research except as cited in the references. The thesis 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 report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Master of Mechanical Engineering.

Signature	:	
Supervisor Name	:	Dr. Nadlene Binti Razali
Date	:	23.1.2023

DEDICATION

To my parents.

ABSTRACT

This research aims to address the problem of the remaining boiler tube life according to the Larson-Miller parameter (LMP). Boiler tubes are used in a wide variety of industrial applications and are subject of deterioration due to corrosion and other environmental damage. It is estimated that 10% of all power plant breakdowns are caused by creep fractures of boiler tubes. Additionally, 30% of all tube failures in boilers and reformers are a result of creep. This deterioration can cause significant damage to the boiler and its associated equipment, leading to decreased efficiency and increased downtime. Therefore, the evaluation of boiler tube remaining life is essential in order to ensure the continued reliability and performance of the boiler system. The LMP is a widely accepted tool for evaluating the remaining life of boiler tubes which is based on a combination of temperature, stress and time. The LMP is used to calculate the remaining life of boiler tubes and is based on the assumption that the boiler tube will fail when the LMP reaches a certain critical value This research aims to analyse the LMP, its limitations and its ability to accurately predict the remaining life of boiler tubes. From the study it shows that LMP is a theoretical method for estimating boiler tube life based on pressure and temperature, but it does not take into account the boiler's condition or atmosphere. The research also reveals that the highest temperature was associated with the lowest stress level i.e., materials with higher LMP values are more susceptible to severe creep damage and as temperature increased in the boiler, the remaining life of the tube decreased significantly (the remaining life of a tube SA 213 was less than 300 hours at 1139 K).

JANGKA HAYAT TIUB DANDANG BERDASARKAN KEPADA LARSON MILLER PARAMETER.

ABSTRAK

Matlamat penyelidikan ini adalah untuk menangani masalah baki hayat tiub dandang mengikut parameter Larson-Miller (LMP). Tiub dandang digunakan dalam pelbagai jenis aplikasi perindustrian dan tertakluk kepada kemerosotan akibat kakisan dan kerosakan alam sekitar yang lain. Dianggarkan 10% daripada semua kerosakan loji janakuasa disebabkan oleh keretakan rayapan tiub dandang. Selain itu, 30% daripada semua kegagalan tiub dalam dandang dan reformer adalah akibat daripada rayapan. Kemerosotan ini boleh menyebabkan kerosakan yang ketara pada dandang dan peralatan yang berkaitan, yang membawa kepada penurunan kecekapan dan peningkatan masa henti. Oleh itu, penilaian baki hayat tiub dandang adalah penting untuk memastikan kebolehpercayaan dan prestasi sistem dandang yang berterusan.LMP ialah alat yang diterima secara meluas untuk menilai baki hayat tiub dandang yang berdasarkan gabungan suhu, tegasan dan masa. LMP digunakan untuk mengira baki hayat tiub dandang, dan berdasarkan andaian bahawa tiub dandang akan gagal apabila LMP mencapai nilai kritikal tertentu. Daripada kajian menunjukkan bahawa LMP adalah kaedah teori untuk menganggar hayat tiub dandang berdasarkan tekanan dan suhu, tetapi ia tidak mengambil kira keadaan atau suasana dandang. Penyelidikan juga mendedahkan bahawa suhu tertinggi dikaitkan dengan tahap tegasan terendah iaitu, bahan dengan nilai LMP yang lebih tinggi lebih terdedah kepada kerosakan rayapan yang teruk dan apabila suhu meningkat dalam dandang, baki hayat tiub berkurangan dengan ketara (baki hayat tiub SA 213 adalah kurang daripada 300 jam pada 1139 K).

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I extend my deepest gratitude to You for the protection and guidance that has been bestowed upon me.

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Nadlene Binti Razali from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for her essential supervision, support and encouragement towards the completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 Background

Boilers are critical components in many industrial processes and power plants and are used to generate steam or hot water for a variety of applications. The high temperatures and pressures inside boilers can cause a range of damage mechanisms, including creep (Duarte, Espejo and Martinez, 2017). Creep is a phenomenon that occurs when a material is subjected to high temperatures and stress over a prolonged period of time, leading to a gradual deformation of the material. This can have a significant impact on the remaining life of boiler tubes, and therefore it is important to understand and predict high temperature creep damage in boilers.

High temperature creep damage in boilers can have a significant impact on the remaining life of boiler tubes. The creep damage can lead to the formation of voids, which can weaken the structure of the tube and make it more susceptible to failure. This can lead to reduced efficiency, increased downtime, and even failure of the boiler. Therefore, it is important to understand and predict high temperature creep damage in boilers.

Creep is a phenomenon in which a material undergoes permanent deformation when subjected to sustained loads or stresses at elevated temperatures. The rate at which creep occurs depends on the material, its composition, and the temperature, pressure, and duration of the load (Maziasz, 2014). As the temperature increases, the rate of creep increases, and at temperatures above a certain threshold, which is known as the creep temperature, creep can occur at a rapid rate.

Boiler creep damage is a significant issue in many industrial systems and can lead to decreased efficiency and increased downtime. The accurate evaluation of boiler tube remaining life is essential in order to ensure the continued reliability and performance of the boiler system. One of the commonly used methods for evaluating the remaining life of boiler tubes is the Larson-Miller parameter , widely accepted tool that is based on a combination of temperature, stress, and time. It is based on the assumption that a boiler tube fails when the LMP reaches a certain critical value (Ghatak and Robi, 2015). In this thesis, the examination involves the use of the Larson-Miller parameter (LMP) for predicting boiler creep damage.

1.2 Problem Statement

One of the main concerns in the operation of water tube boilers is creep damage, which occurs when the material of the boiler tubes is subjected to high temperatures and stresses over a prolonged period of time (Chaudhuri, 2006). The prolonged exposure to high temperatures causes the material to undergo deformation, leading to the weakening and eventual failure of the boiler tubes. This can result in significant damage to the boiler and its associated equipment, leading to decreased efficiency and increased downtime.

The LMP is widely used as a tool for evaluating the remaining life of boiler tubes in relation to creep damage (Nucci, Narvaez and Krettenauer, 2014). The LMP is based on a combination of temperature, stress, and time, and is used to calculate the remaining life of boiler tubes by assuming that the boiler tube shall fail when the LMP reaches a certain critical value.

However, it is important to note that the LMP is based on several assumptions and simplifications and may not always accurately predict the remaining life of boiler tubes in real-world scenarios (Holcomba *et al.*, 2013). Therefore, it is crucial to conduct regular inspections and monitoring of the boiler tubes to detect any signs of creep damage and to implement proper maintenance and replacement strategies to prevent failure.

In addition, alternative methods for predicting creep damage in boiler tubes, such as finite element modelling and experimental studies, have also been proposed (Gutiérrez Ortiz, 2011). These methods may provide more accurate predictions and should also be considered when evaluating the remaining life of boiler tubes.

Therefore creep damage is a major concern in the operation of fire tube and water tube boiler, and regular monitoring and proper maintenance are crucial to ensure the reliability and performance of the boiler system. The LMP is a widely accepted tool for evaluating the remaining life of boiler tubes in relation to creep damage, but it is important to consider the limitations and assumptions of the LMP, and to also consider alternative methods for predicting creep damage.

1.3 Objectives of Research

The following are the objectives that govern this research:

i) To analyse the limitations of the LMP and its ability to accurately predict boiler creep damage.

ii) Analyse the LMP method in predicting boiler creep damage under different operating conditions.

1.4 Scope of Research

The scope of this research is to investigate the extent of using the Larson-Miller parameter (LMP) for predicting the remaining life of boiler tubes. Boiler tubes are a crucial component in many industrial systems and are susceptible to deterioration due to a variety of factors including high temperature and pressure, corrosion, and environmental damage. The accurate evaluation of boiler tube remaining life is essential in order to ensure the continued reliability and performance of the boiler system.

In order to investigate the scope of using the LMP for predicting the remaining life of boiler tubes, this research reviews the theoretical background of the LMP and its underlying assumptions.

a) The limitations of the LMP and its ability to accurately predict the remaining life of boiler tubes.

b) Alternative methods of predicting the remaining life of boiler tubes and their comparison with the LMP.

c) Applications of the LMP in industry and its practical limitations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To determine the remaining life according to Larsson-Miller a study of existing literature with respect to the relevant topics are reviewed. The succeeding sections are intended to lay the groundwork for the design ideation process.

2.2 Water Tube Boilers

A water tube boiler is a type of boiler in which water circulates in tubes that are heated externally by the combustion of fuel. The hot gases produced by the combustion process pass around and through the tubes, heating the water inside the tubes, which then turns into steam. Water tube boilers are typically more efficient and have a higher steam-generating capacity than fire tube boilers (Taylor, 1996).

One of the key advantages of a water tube boiler is its ability to generate steam at high pressures and temperatures, making it suitable for power generation and industrial process applications. Water tube boilers are also able to handle a wide range of fuels, including coal, oil, and gas, and can be designed to operate with multiple fuel sources, The history of the water tube boiler dates back to the early 19th century. The first patent for a water tube boiler was issued in 1867 to George Babcock and Steven Wilcox, who were both engineers working in the United States (Taylor, 1996). Their design, known as the Babcock and Wilcox boiler, consisted of a series of water-filled tubes that were surrounded by a furnace. This design was more efficient and had a higher steam-generating capacity than the traditional fire tube boilers that were in use at the time. In the following years, several other engineers and inventors made improvements to the design of water tube boilers, such as the addition of superheaters and economizers. These enhancements made water tube boilers even more efficient and suitable for use in power generation and industrial process applications.

During the 20th century, water tube boilers became the preferred choice for power generation and industrial process applications due to their high steam-generating capacity and efficiency. They were also used in ships and submarines, due to their compact size and ability to generate steam quickly (Taylor, 1996). One of the most significant advancements in recent years has been in the field of metallurgy. The development of new and improved materials has had a major impact on the efficiency, safety, and reliability of boilers.

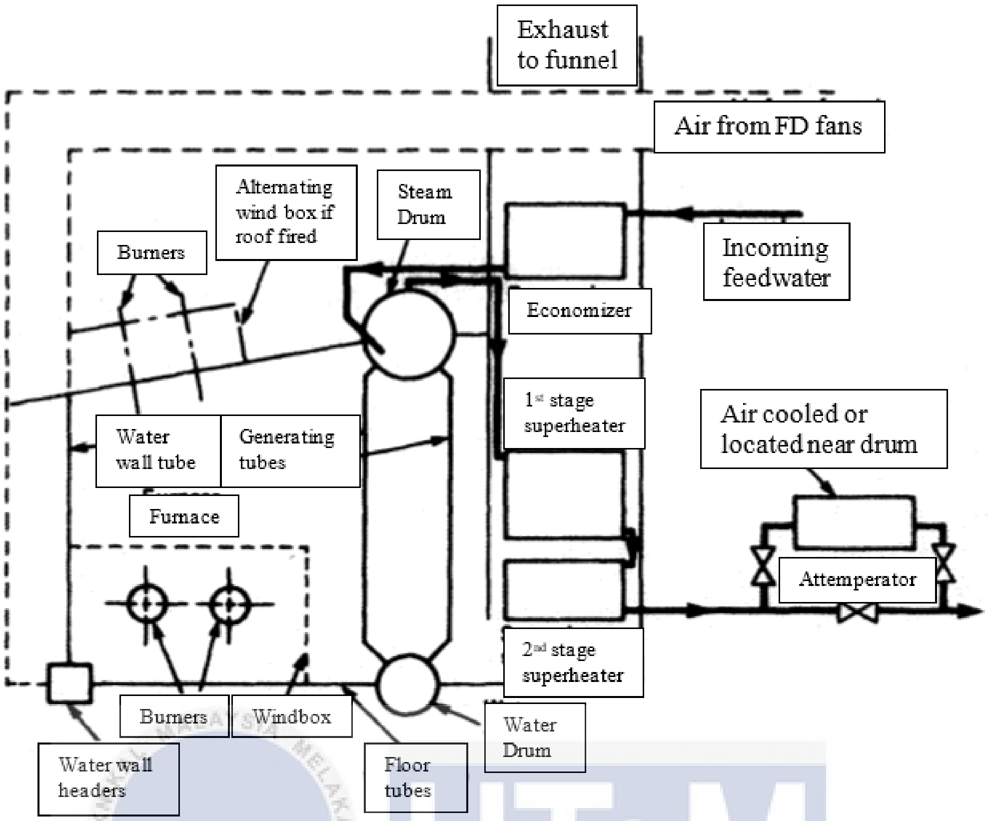

Figure 2.1 Water tube boiler arrangement (Taylor, 1996).

One of the major advancements in metallurgy that has had an impact on boilers is the development of high-temperature alloy materials. These materials, such as alloy steel and nickel-based alloys, have significantly improved the creep resistance of boilers. Creep is the gradual deformation of a material under a constant load and is a major concern in boilers because it can lead to failure. The use of high-temperature alloy materials has greatly improved the safety and reliability of boilers (Tamura *et al.*, 2013). Another major advancement in metallurgy that has had an Impact on boilers is the development of advanced coatings and cladding. These coatings and cladding can protect the boiler tube surface from corrosion and erosion, which can greatly extend the life of the boiler. This has been particularly beneficial for boilers that operate in harsh environments, such as those found in power plants and oil refineries (Duarte, Espejo and Martinez, 2017). In addition, the use of computer-aided design and simulation tools has greatly improved the design and optimization of boilers. These tools allow for the accurate prediction of thermal performance and stress distribution, which leads to improved safety and reliability Overall, the advancements in metallurgy have had a major impact on the development of boilers. The use of high-temperature alloy materials, advanced coatings and cladding, and computer-aided design and simulation tools have greatly improved the efficiency, safety, and reliability of boilers (Kuprianov, 2005). These improvements have played a critical role in the widespread adoption of boilers in a wide range of industrial and power generation applications.

Another advancement in water tube boiler technology is the use of advanced controls and automation systems. These systems allow for precise control of the boiler's operations, including temperature, pressure, and fuel consumption. This improves the efficiency of the boiler and reduces emissions (Kuprianov, 2005). Additionally, advanced safety systems such as pressure relief valves, temperature and pressure sensors, and emergency shut-off valves have been developed to improve the safety of water tube boilers. Additionally, the use of computerized simulation and modelling techniques is another advancement in the water tube boiler technology. These techniques allow engineers to analyse and optimize the performance of the boiler and identify any potential issues before they occur. This leads to more efficient and reliable boilers.

Modern boilers are designed to be more environmentally friendly by reducing emissions and increasing energy efficiency. One-way modern boilers are more environmentally friendly is by utilizing low-emission combustion technologies. These technologies include the use of low-NOx burners, which reduce nitrogen oxide emissions, and flue gas recirculation, which reduces the amount of oxygen available for combustion and thus reduces the amount of NOx produced (Kuprianov, 2005). Additionally, modern boilers are also designed to minimize the release of particulate matter into the atmosphere.

Another way modern boilers are more environmentally friendly is by increasing energy efficiency (Nicoletti *et al.*, 2021). This is achieved by using more advanced heat exchanger designs and improved controls, which allow for more precise control of the boiler's operations. Additionally, modern boilers can utilize renewable energy sources, such as biomass and solar energy, which reduces the use of fossil fuels and associated greenhouse gas emissions.

Finally, modern boilers are also designed with improved safety features, which can prevent accidents and damage to the environment, this includes emergency shut off valves and pressure relief valves, also automatic controls that can shut off the boiler in case of emergency.

To put in simpler terms, modern boilers are designed to be more environmentally friendly by reducing emissions and increasing energy efficiency through the use of low-emission combustion technologies, advanced heat exchanger designs, and improved controls (Mentl and Liska, 2007). Additionally, the use of renewable energy sources, and improved safety features can prevent accidents and damage to the environment.

There are several types of fuels that can be used in boilers, each with its own environmental impacts.

Coal is one of the most commonly used fuels in boilers. It is a fossil fuel that is abundant and relatively inexpensive. However, burning coal releases significant amounts of carbon dioxide, a greenhouse gas that contributes to global warming. In addition, coal mining can have negative environmental impacts, such as deforestation and water pollution.

Natural gas is another commonly used fuel in boilers. It is a fossil fuel that burns cleaner than coal, releasing less carbon dioxide per unit of energy. However, natural gas is still a fossil fuel and its extraction and transportation can have negative environmental impacts, such as air and water pollution, and the release of methane, a potent greenhouse gas.

Biomass, such as wood chips, agricultural waste, and sewage sludge, can also be used as fuel in boilers. Biomass is considered a renewable energy source because it is derived from recently living organisms and can be replenished over time. However, the sustainability of biomass energy depends on the source of the biomass and the way it is grown and harvested.

Oil is another fossil fuel that is used in boilers, similar to natural gas and coal, oil also releases carbon dioxide and other pollutants when burned. Furthermore, oil extraction and transportation can have negative environmental impacts.

Nuclear energy is also used in some boilers, although it is not a fuel, it produces energy that is used to heat water or other fluids to generate steam. Nuclear power is a low-carbon source of energy but has a long-term waste storage issue, and the risk of accidents or terrorist attacks.

Different types of fuels have different environmental impacts when used in boilers. Coal and oil are the most polluting fossil fuels, natural gas has lower emissions than coal, but still releases greenhouse gases, Biomass is considered a renewable energy source but depends on the source and the way it is grown and harvested, and nuclear energy is low-carbon source but has long-term waste storage issues.

2.3 Common Damages on Boiler

Boiler tubes are an essential component in power plants and are responsible for carrying high-pressure steam and hot gases throughout the system. These tubes are usually made of steels and alloys that are designed to withstand high temperatures and pressures. However, prolonged exposure to high temperatures and pressures can lead to damage of the boiler tubes, which can have a significant impact on the safety and efficiency of the power plant.

2.3.1 Deposit

Deposit-related problems in boilers can have a significant impact on their performance and efficiency. Some common deposit-related problems in boilers include:

i. Scale formation: Scale is a buildup of minerals on the inside of the boiler tubes. This can occur when the water used in the boiler has a high mineral content. Scale can insulate the tubes, reducing heat transfer and causing the boiler to work harder to maintain the desired temperature.