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# Literature Review: Remaining Life Assessment Method of Heat Recovery Steam Generator (HRSG) Based on American Society Of Mechanical Engineers (ASME) Standards

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## *ABSTRACT*

*The role of power plants in the energy sector, such as Heat Recovery Steam Generators (HRSG), often faces challenges of performance degradation due to corrosion, fouling, and thermal fatigue. This study aims to evaluate the factors affecting HRSG performance and the mitigation efforts for these issues. This review aims to analyze studies conducted in Indonesia on the remaining life assessment methods of HRSG based on the American Society of Mechanical Engineers (ASME) standards. The literature review was conducted by collecting and analyzing references from ASME standards through national journals found via Google Scholar, published between 2018 and 2024. The data includes the methods and analyses used in the remaining life assessment of HRSG. The assessment methods for HRSG remaining life include corrosion rate calculation, stress rupture testing using the Larson-Miller Parameter (PLM), material degradation analysis, the Risk-Based Inspection (RBI) approach, as well as pipe thickness evaluation and allowable working pressure assessment. There is no single method that can comprehensively provide an effective HRSG remaining life assessment. Each method has its own advantages and limitations.*

***Keywords:*** *Heat Recovery Steam Generator, remaining life assessment, ASME standards, corrosion, Risk-Based Inspection, Larson-Miller Parameter.*

## ABSTRAK

Latar belakang: Peran pembangkit listrik pada sektor energi seperti Heat Recovery Steam Generator (HRSG) seringkali menghadapi tantangan penurunan kinerja akibat korosi, fouling, dan thermal fatigue. Penelitian ini bertujuan untuk mengevaluasi faktor-faktor yang mempengaruhi kinerja HRSG dan upaya mitigasi terhadap masalah tersebut. Tujuan: Review ini bertujuan untuk menganalisis beberapa penelitian di Indonesia tentang metode penilaian sisa umur Heat Recovery Steam Genearator (HRSG) berdasarkan Standar American Society Of Mechanical Engineers (ASME). Metode: Literature review ini dilakukan dengan mengumpulkan dan menganalisis berbagai referensi dari standar ASME berdasarkan jurnal nasional melalui mesin pencarian Google scholar yang diterbitkan antara tahun 2018 hingga 2024. Data yang digunakan mencakup metode dan analisis yang digunakan dalam penilaian sisa umur Heat Recovery Steam Generator. Hasil: Metode penilaian sisa umur HRSG terdiri dari perhitungan laju korosi, uji stress rupture dengan Parameter Larson-Miller (PLM), analisis degradasi material, pendekatan Risk Based Inspection (RBI), serta evaluasi ketebalan pipa dan tekanan kerja yang diizinkan. Kesimpulan: Tidak ada metode tunggal yang mampu memberikan gambaran lengkap terhadap penilaian sisa umur HRSG yang efektif. Setiap metode memiliki kelebihan dan keterbatasan masing-masing.

**Kata Kunci** : Heat Recovery Steam Generator, Penilaian Sisa Umur, ASME Standard, Korosi, Risk-Based Inspection, Larson-Miller Parameter.

## INTRODUCTION

The role of power plants is crucial to support activities in various sectors, especially for the oil and gas exploration sector. One important component, such as the Heat Recovery Steam Generator (HRSG), plays a vital role in the combined cycle of power plants by utilizing waste energy from gas turbine exhaust to produce high-pressure steam (Ganapathy, 2003). Through this utilization, HRSG can increase the overall system efficiency by 50-60%, far exceeding the efficiency of single-cycle based power plants (Kehlhofer et al., 2009).

However, in long-term operation, HRSG is not immune to technical challenges. Corrosion, fouling, and thermal fatigue pose serious threats that can degrade HRSG performance and design life (Dooley & Bursik, 2012). Corrosion can occur due to the accumulation of acidic condensate on the pipe surface, while fouling is caused by the accumulation of particles and compounds on heat transfer surfaces, reducing heat transfer efficiency (Powers, 2011). Thermal fatigue, on the other hand, occurs due to repeated heating and cooling cycles, causing micro-cracks in the material (Viswanathan, 2008).

Understanding these degradation mechanisms is crucial to maintaining operational reliability and extending the lifespan of HRSG in modern power plant systems. The remaining life assessment (RLA) of HRSG is important to ensure operational reliability and safety, thus avoiding failures that can cause costly downtime and safety risks (Smith et al., 2020).

HRSG remaining life assessment involves a comprehensive analysis of material conditions, operational pressure, and thermal loads experienced by the component. In Indonesia, the use of HRSG in power plants is increasing along with the growing energy demand. However, the main challenges faced are the lack of historical data and limited resources to conduct periodic remaining life assessments. Most HRSG remaining life assessment methods still rely on traditional approaches, which are often inaccurate and unable to accommodate complex operational condition variations (Prasetyo et al., 2022).

This study aims to estimate the remaining operational life and plan appropriate reconditioning or replacement actions, focusing on early detection of potential damage such as cracks and corrosion, thereby preventing risks that could endanger workers and harm the industry based on American Society of Mechanical Engineers (ASME) standards. ASME standards, such as the Boiler and Pressure Vessel Code (BPVC) and API 579-1/ASME FFS-1, provide guidelines for design measurements, periodic inspection obligations, and component integrity assessment based on in-depth analysis. ASME methods have proven effective in identifying potential damage, such as cracks and corrosion, so that corrective actions can be taken before risks occur and endanger workers and harm the industry (Yeh et al., 2003).

## METHODOLOGY

This literature review was conducted by collecting and analyzing various references from ASME standards based on national journals through the Google Scholar search engine, published between 2018 and 2024. The data used includes methods and analyses used in the remaining life assessment of Heat Recovery Steam Generator (HRSG), including corrosion rate calculation, stress rupture testing with the Larson-Miller Parameter (PLM), material degradation analysis, Risk Based Inspection (RBI) approach, as well as pipe thickness evaluation and allowable working pressure. This review aims to provide a comprehensive overview related to HRSG remaining life assessment and recommendations for its application in the power plant industry.

**RESULT**

In an effort to accurately and standardized assess the remaining life of Heat Recovery Steam Generators (HRSG), various studies have been conducted referring to approaches and methods in accordance with ASME provisions. Based on the results of the collected literature study, the following is a summary of the methods used by several researchers in evaluating HRSG remaining life:

| No. | Author | Title | Method | Description |
|---|---|---|---|---|
| 1. | Wibowo et al., (2020) | Prediction of HRSG Remaining Service Life Based on Pipe Thickness with Non Destructive Test (NDT) Method | Corrosion Rate and Remaining Life Calculation | Calculating the corrosion rate on HRSG pipes and estimating remaining life based on the minimum allowable thickness according to ASME Boiler and Pressure Vessel Code Section I and Section II Part D. |
| 2. | Wahyudi and Iswanto (2023) | Analysis of the Remaining Service Life of Heater Tubes in HRSG with Stress Rupture and Larson-Miller Parameter Method. | Stress Rupture Test and Larson-Miller Parameter (PLM) | Performing stress rupture tests on pipe material specimens, then plotting the results on a PLM curve to extrapolate the remaining life of the material. |
| 3. | Wahyudi, (2021) | Failure Analysis and Remaining Service Life Calculation of SA 106 C Heater Pipe in HRSG. | Material Degradation Analysis and Material Test | Evaluation of material degradation through a series of tests such as composition test, tensile test, hardness test, and microstructure observation to determine the remaining life of HRSG heater pipes. |
| 4. | Hardianto et al., (2021) | Analysis of Remaining Life Determination with Semi-Quantitative RBI Method Approach | Risk Based Inspection (RBI) with Semi-Quantitative Method | Using a semi-quantitative RBI approach to determine the riskiest pipe sections and calculate the remaining service life of pipeline according to ASME B31.8 and API 570 standards. |
| 5. | Santoso et al., (2024) | Evaluation of remaining life and maximum allowable working pressure on low pressure evaporator HRSG. | Pipe Thickness and Corrosion Rate Evaluation | Calculating corrosion rate, minimum thickness, remaining life, and wall stress on HRSG pipes to determine safe operational conditions. |
| 6. | Dooley, B. (2024) | The Importance of HRSG HP Evaporator Tube Internal Deposit Evaluation | HRSG Internal Deposit Evaluation | Focuses on the importance of internal deposit evaluation in HRSG high pressure evaporator tubes to detect flow accelerated corrosion (FAC) and under-deposit corrosion (UDC), and its role in optimal cycle chemistry development. |
| 7. | Raja, A. (2022). | Availability analysis of heat recovery steam generators used in thermal power plants | Availability and Failure Analysis | Analyzes failures and damage in HRSG, including cracking and thermal stress fatigue, and the importance of root cause analysis to improve operational reliability. |
| 8. | Dooley, B. (2024) | EHF2024: Highlighting new challenges for HRSG reliability | HRSG Discussion and Case Study | New challenges in HRSG reliability, such as flexible operation, the impact of increased renewable energy capacity, and the importance of flow accelerated corrosion and under-deposit corrosion assessment. |

The corrosion rate calculation method shows that the HRSG pipe corrosion rate ranges from 0.047 mm/year to 0.101 mm/year, with remaining life varying between 7.1 and 66.4 years depending on the minimum allowable thickness (Wibowo et al., 2018). The results of stress rupture tests combined with the Larson-Miller Parameter (PLM) indicate that the remaining life of HRSG pipes can be estimated with a more conservative approach, where the PLM constant value affects the estimation of pipe service life, with results between 1,425 and 3,253 hours under certain operating conditions (Wahyudi and Iswanto, 2023). Material degradation analysis shows a decrease in tensile strength and microstructure changes in HRSG pipe material that has been operating for a long time. Composition, hardness, and tensile tests indicate that the material experienced significant degradation due to high temperature and operating pressure, with an estimated remaining life of approximately 3,518 hours at a design temperature of 385°C (Wahyudi, 2021). The Risk Based Inspection (RBI) method with a semi-quantitative approach shows that pipes with a high risk level require further inspection and strict monitoring to prevent failure due to corrosion and material fatigue (Setiawan et al., 2022). Evaluation of pipe thickness and working pressure indicates that the maximum working pressure limit is still within a safe range, but a high corrosion rate can cause accelerated thinning of the pipe wall which has the potential to significantly reduce the service life of the HRSG (Santoso et al., 2024).

## DISCUSSION

Remaining life assessment of Heat Recovery Steam Generator (HRSG) is an important evaluation in ensuring safe and efficient operational reliability in power plants. Assessments using ASME standards, such as the Boiler and Pressure Vessel Code (BPVC) and API 579-1/ASME FFS-1, offer a structured and data-driven approach to evaluating the condition and integrity of critical HRSG components. These standards provide clear guidelines regarding periodic inspection obligations, damage analysis, and assessment of potential material damage, such as cracks, corrosion, and thermal fatigue. With this approach, the assessment process can identify problems early, estimate the remaining operational life, and provide appropriate recommendations for reconditioning or replacement actions. This not only ensures the reliability and operational safety of HRSG but also helps reduce the risk of failures that can endanger workers and harm the industry, thereby increasing efficiency and optimizing maintenance costs.

The corrosion rate calculation method, as performed by Wibowo et al. (2020), provides an estimate of remaining life based on pipe thickness measurements and corrosion rate using the Non Destructive Test (NDT) method. This approach is considered quite simple and practical. However, accuracy is highly dependent on the consistency of the corrosion rate over time and the assumption that corrosion occurs simultaneously. In practice, the corrosion rate can be affected by various factors such as variations in operating conditions and water quality. The estimation of remaining life assessment may not always be accurate. In the context of research by Wahyudi and Iswanto (2023), the stress rupture test method combined with the Larson-Miller Parameter (PLM) is considered more comprehensive compared to other test methods because it is able to consider two main factors that affect material life simultaneously, namely operating temperature and stress. The Larson-Miller Parameter provides an estimate of material life based on a combination of temperature and stress applied during testing, providing a more complete picture of material resistance under actual operating conditions. This method can produce more accurate and representative predictions of material life that are more relevant to actual operational conditions, compared to methods that only test one factor, such as only measuring temperature or stress without considering both.

However, this comprehensiveness also comes with certain limitations. This test requires more time and resources because it involves testing at various temperatures and stresses to produce more complete data. In addition, the results obtained are also influenced by material variability (e.g., differences in composition or material quality between samples) and testing conditions (such as the accuracy of temperature or stress control), which can lead to varying results and affect the accuracy of material life estimation.

So, although more comprehensive, this method requires more investment in terms of time, cost, and precision in conducting tests, which can be a challenge in practical field applications. Material degradation analysis through composition tests, tensile tests, hardness tests, and microstructure observations, as conducted by Wahyudi (2021), provides an in-depth understanding of material conditions in real time. This method identifies specific degradation mechanisms that occur in the material, such as changes in microstructure or a decrease in mechanical strength. The limitation of this method is that it is destructive and requires material samples that may not always be available or samples taken without affecting component integrity. In addition, the Risk Based Inspection (RBI) approach with a semi-quantitative method, as applied by Hardianto et al. (2021), provides a method for prioritizing inspections based on risk level. This method is considered effective in identifying high-risk areas that require further attention. However, the limitation is that the accuracy of the risk assessment is highly dependent on the quality of the data used and expertise in risk analysis. Evaluation of pipe thickness and working pressure performed by Santoso et al. (2024), provides important information about the operational limits of each component. This method provides a general overview of the condition of each component, but the limitation of this approach is that it cannot detect material degradation that does not significantly affect thickness or pressure. Overall, no single method can provide a complete picture of HRSG remaining life assessment. The most effective approach is to combine several methods to obtain more accurate and comprehensive results. In addition, it is very important to consider factors such as specific operating conditions, maintenance history, and material characteristics in conducting HRSG remaining life assessment.

## KESIMPULAN

Based on the results of the literature review, various methods are used to assess the remaining life of Heat Recovery Steam Generators (HRSG) in several industries in Indonesia. Each method has its own advantages and limitations. From the various methods that have been studied, the best approach is to combine several methods to obtain more accurate and comprehensive results. In addition, periodic inspections and proper maintenance are very important to ensure that HRSG continues to operate safely and efficiently in the long term. Further research combining several methods is needed to add references for HRSG remaining life assessment.

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