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Analysis of Thermite Rail Joint Damage in Curve Section 3 of Lrt Jakarta

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Abstract: This study analyzes the damage to the Alumino Thermit Welding (ATW) rail joints in the curved Section 3 between Pulomas Station and Boulevard Selatan Station of the Jakarta LRT. Using a qualitative method with a cause-and-effect approach through a fishbone diagram, the study identifies the factors causing the damage. The results show that the damage is classified as Surface Defect. The primary contributing factors are the small curve radius, imbalance of train wheels, and the driving technique of the train operator, with the highest frequency at 46.15%. This is followed by inspections conducted only visually at night with limited lighting, contributing 38.46%. Material factors have the smallest contribution, at 15.38%. For repairs, it is recommended to use methods such as patching with electric welding, grinding, and re-welding, along with routine inspections using Ultrasonic Testing. Coordination with the OCC and Crew Unit Leaders (train operators) regarding the recommended speed limits on curves is crucial, and the implementation of sensor technology for real-time monitoring of rail conditions should also be considered.

Keywords: Alumino Thermit Welding, Welding Joints, Rail Defects, Fishbone Diagram, LRT Jakarta

INTRODUCTION

Jakarta is the most densely populated city at 14.1 million people. This density occurs because of the many community activities in various fields including economic, social, political, and cultural. Sufficient and proper transportation access is needed for all residents of Jakarta to support community activities (Prawata, 2014). Jakarta has complicated transportation problems. One of them is the traffic density that is still difficult to overcome. Jakarta has a road length of 7% of the city area, when seen in large cities in developed countries the road length can reach 12-15% percent of the city area. This is due to a number of reasons, including high mobility needs and Jakarta residents who make private vehicles a mandatory mobility need, according to (Jakarta.bps.go.id) in (Mu'allimah & Mashpufah, 2021).

To solve the congestion problem in Jakarta, public transportation is needed that can accommodate many people and is fast, safe, and comfortable. Transportation that can change people's perspectives to reduce the use of private vehicles that can cause traffic congestion. In 2015, the Jakarta Government commissioned PT Jakarta Propertindo to build Light Rail Transit (LRT). With the aim of reducing air pollution generated by private vehicles and saving travel time, the Jakarta LRT was built with international standards as a safe and comfortable mode of public transportation (Pramudita & Nataadmadja, 2023).

Mentioned in Governor Regulation No. 95 of 2019 "Integrated Highway / Light Rail Transit, hereinafter abbreviated as LRT, is mass transportation based on rail roads or special lines with a light rail / light rail transit system that operates quickly, comfortably, safely, scheduled and high frequency.". Jakarta LRT Phase 1A has a span of 5.746 km with 6 elevated stations including Pegangsaan Dua Station, South Boulevard Station, North Boulevard Station, Pulomas Station, Equestrian Station, and Velodrome Station. Jakarta LRT phase 1A has been actively operating from 2019 until now. Now work is underway on the Jakarta LRT phase 1B project (Velodrome - Manggarai) starting construction in October 2023. Phase 1B has a span of 6.4 km with 5 elevated stations including Rawa Mangun Youth Station, Pramuka BPKP Station, Pasar Pramuka Station, Matraman Station, and Manggarai Station (Nelfira, 2023). The Jakarta LRT is a light railroad with a carrying capacity twice as large as the Transjakarta bus. In addition, another advantage is that it has its own lane, so it is not disturbed by other traffic and can get to the destination quickly without being disturbed by congestion.

Jakarta LRT is a rail transportation system in Jakarta that plays an important role in overcoming traffic congestion. The reliability and safety of railroad operations is highly dependent on the condition of the rail line, one of which is the rail connection. One of the rail connections used in the Jakarta LRT is Alumino Thermit Welding (ATW). Alumino Thermit Welding (ATW) is a welding technology used in various countries because of its advantages, namely low price, high mobility, and operator expertise that is not too difficult. This technology was developed by Goldscmidt in 1986. Thermit welding is a process for connecting metal ends with high heating which causes a reaction between iron powder and alumina (Ihlas, 2017). Even so, it does not rule out the possibility that by using Thermit welding technology on rail joints damage can occur, especially on rail curves.

Curves on rail lines have greater lateral pressure than straight lines. This pressure can cause damage to the rail especially at joints such as chipping, cracking, or wear. Therefore, it is necessary to analyze the damage of thermite welded rail joints (Case Study: Curved Section 3 Pulomas Station - South Boulevard Station LRT Jakarta). This analysis is to help identify factors that can affect damage to Thermit welded rail joints.

Literatur Review

Railroad Geometry

Railway geometry includes the shape and size of the rail line both horizontally and vertically, including rail measurements, slopes, curves, and track widening (Jessy Kartini et al., 2021). The main aspects of railroad geometry include:

a. Railroad Width: The standard widths in Indonesia are 1067 mm and 1435 mm, commonly used in Java and Sumatra. Railway widening is done on horizontal curves, depending on the radius of the curve and following the tolerances set in the Minister of Transportation Regulation No. 60 of 2012.
b. Slope: Regulates the slope or ascent of the track to maintain the safety and stability of train travel. There is a maximum limit for slope in the emplacement, which is 1.5‰, and needs to be reduced if there are curves or tunnels to maintain balance.
c. Vertical and Horizontal Curves: Vertical curves are projections of rails on a vertical plane that adjust to the plan speed. Meanwhile, horizontal curves connect straight tracks

with curved sections. Both types of curves require special attention in design, especially regarding the minimum radius that affects the safe operation of trains.

d. Widening and Raising Railways: Widening is required to allow unimpeded wheel movement through curves. Elevation of the outer rail in curved areas is done to offset the centrifugal force, which is determined based on the plan speed and radius of the curve.

These standards are regulated in Minister of Transportation Regulation No. 60 Year 2012, which provides technical guidelines in the construction and maintenance of rail lines to ensure the safety and convenience of railway operations.

Alumino-Thermic Welding (ATW)

Alumino-Thermic Welding (ATW) is a rail joining process that utilizes superheated molten metal resulting from the thermite reaction between metal oxides and aluminum. This process, known as the Gold Schmidt process, was first developed by Professor Hans Gold Schmidt in 1896 (IRICEN, 2014).

The process is used to join rail ends by pouring molten steel into a refractory mold set around the gap between two rails. For optimal welding results, the rail ends must be properly aligned and cleaned of rust, dirt and grease.In addition, the rails are preheated to ensure complete fusion between the molten steel and the base metal of the welded rail. ATW is widely applied worldwide due to its effectiveness in creating strong and durable rail joints.

Types of rail defects

a. Weld Defects: Usually occurs at the head, body, or base of the rail. Some typical cases are rail cracks that can progress from the defect to one or both ends of the adjoining rail. If the defect in the weld joint develops longitudinally, it is considered to require piercing for repair.
b. Squat Defect: A defect that occurs in a railroad, where the rail is excessively deformed and causes the geometry of the railroad to be out of alignment.
c. Crushed Head: Damage at the rail head, with the surface sagging to a depth of more than 3/8 inch and a length of about 8 inches, rather than at the joint.

The Objectives of the Study

In this research, there are several objectives to be achieved, including the following:

a. Knowing the damage and the severity of damage that occurs in the Alumino Thermit Welding (ATW) rail joints in the curved section 3 of the St. South Boulevard - St. Pulomas LRT Jakarta plot.
b. Identifying factors that cause damage to Alumino Thermit Welding (ATW) rail joints.
c. Provide recommendations on how to overcome damage to Alumino Thermit Welding (ATW) rail joints.

METHOD

This research uses a qualitative method with a cause and effect approach to analyze the damage to the Thermit welded rail joints in the Section 3 arch, Jakarta LRT. Data sources consist of primary data obtained from observations, interviews with relevant parties, and field documentation, as well as secondary data that includes rail joint damage reports and related literature.

RESULT AND DISCUSSION

Based on the results of the researcher's Grand Tour Observation, the researcher found information on December 17, 2023 that a Thermit welded rail joint defect was found on the curvature of section 3 of the Pulomas Station - South Boulevard Station plot at KM 4+000. On May 29, 2024, the researcher made further observations at the Section 3 curve of the

Pulomas Station - South Boulevard Station plot of the Jakarta LRT, that on the train track between Pulomas Station and South Boulevard Station, six damage points were found which varied in number and severity category, as follows:

1. KM 3+185, Line 1: There is one surface defect with a low category.
2. KM 3+300, Line 1: Two defect surfaces were found with a medium category.
3. KM 3+685, Lane 1: There are three defect surfaces in the medium category.
4. KM 3+705, Lane 1: Found one defect surface in the low category.
5. KM 3+300, Lane 2: There are two defect surfaces in the medium category.
6. KM 3+975, Lane 1: Two defect surfaces were found in the low category.

The damage identified on this line shows a pattern of defect surface distribution, with most of the damage in the low to medium category. This indicates that the condition of the Thermit welded rail joints in the area is degraded and requires further attention, especially at points with higher defect counts and moderate damage categories.

Step One: Identify and Define Problem Statement

This research uses a Fishbone diagram to analyze the factors that cause damage to thermite welded rail joints on the section 3 petask St. Pulomas - St. South Boulevard arch. This research uses the Material, Method, Environment approach to identify problems and their causes.

Material Aspect

Weld maturity and temperature that are not maintained during the welding process can be factors that cause damage. Unstable temperatures during welding can cause rail joints to not form properly, making them more susceptible to damage in the future.

Method Aspect

Maintenance of Thermit Welding rail joints in Jakarta LRT is carried out regularly every six months, in accordance with established procedures. Visual inspection is the main method of routine maintenance, while more in-depth inspections such as ultrasonic tests are conducted once a year. While visual inspections are conducted on schedule, there is a concern that this method may miss damage that is not visible to the naked eye, thus risking not detecting problems at an early stage.

Jakarta LRT also uses tools such as Ultrasonic Test, Panametrics, and Non-destructive testing (NDT) to identify damage. However, there are indications that visual inspection is often the top priority, which may overlook micro-cracks or other damage that is not visible.

Environment Aspect

A major contributing factor to the rail joint damage was the condition of the rail line in Section 3, particularly the small curved radius. The small curve radius causes greater stress on the rail joints, accelerating wear and tear and increasing the risk of damage.

In addition, drivers not adhering to the recommended speed when traversing curves with small radii can also contribute to this damage. Train speeds that do not comply with the recommended limits, as well as train wheel imbalances, also worsen the condition of the rail joints.

Step Two: Development of Fishbone Analysis Diagram Based on Problem Identification

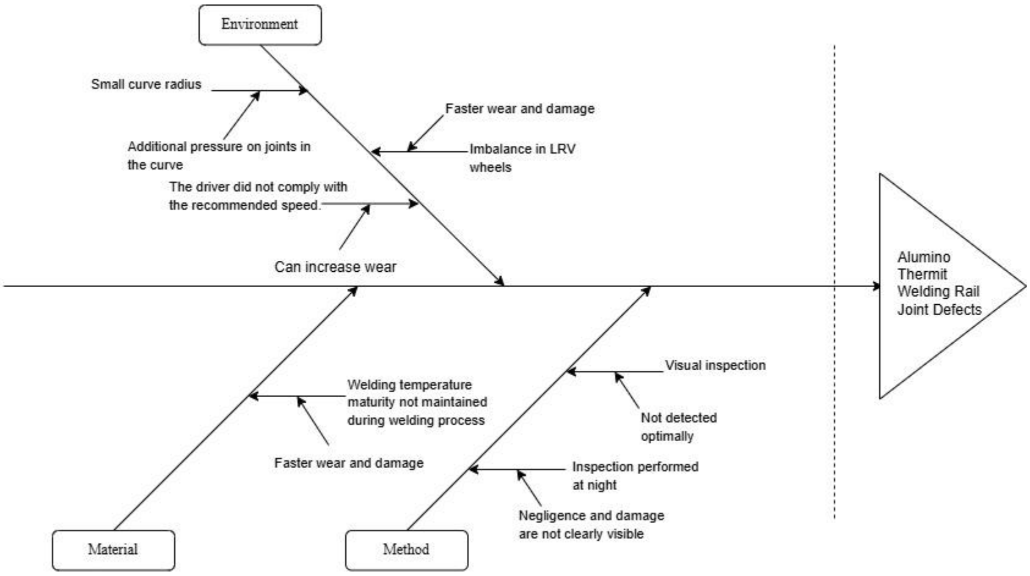

Fig 1. Diagram Fishbone
Source: Analysis Result

Step Three: Finding Potential Causes (Root Causes)

Based on the fishbone analysis diagram that has been made, it can be seen that with this fishbone analysis theory, namely by identifying and finding various causes of problems related to damage to Alumino Thermit Welding rail joints. It can be determined that the main cause that causes damage to the Alumino Thermit Welding (ATW) rail connection on the section 3 curve of the Pulomas Station plot - South Boulevard Station of the Jakarta LRT, namely:

1. Weld maturity and temperature control, greatly affect the durability of the joint. Imperfections in these processes can lead to structural weaknesses that accelerate damage, especially in curved areas.
2. Inspections were conducted only visually and were conducted at night under limited lighting conditions, potentially missing damage or minor changes to the joints.
3. Driver non-compliance with the recommended speed when crossing rail curves is a significant factor. Speeds in excess of recommended limits can increase stress and wear on rail joints, accelerating the onset of damage.
4. Operational conditions such as too small a curve radius and train wheel imbalance put additional stress on the rail joints.

Step four: Establishing Root Causes Using Pareto Diagrams

Table 1. Percentage of Causes of Damage

Cause	Total Frequency	%	% Cumulative
Environment	6	46,15%	46,15%
Method	5	38,46%	84,62%
Material	2	15,38%	100%
Total	13	100%	

Source: Analysis Result

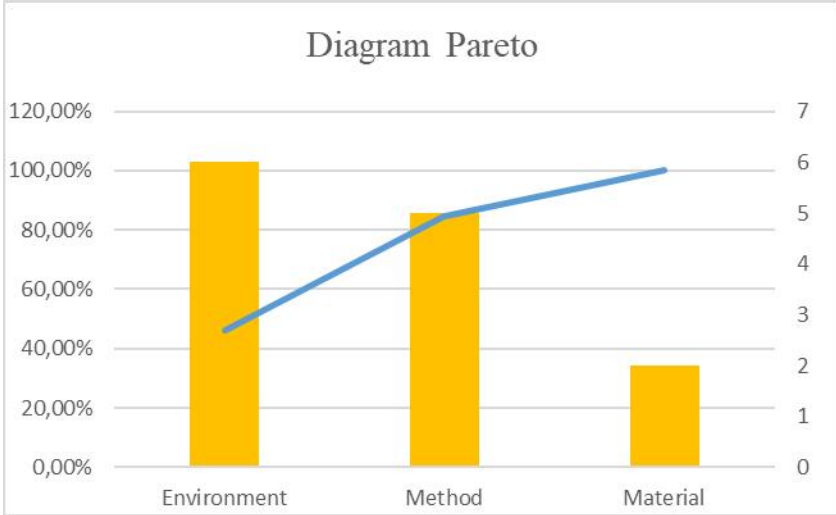

Fig 2. Diagram Pareto
Source: Analysis Result

The frequency of causes of damage is based on data collected from interviews with several informants. The following is a detailed explanation of the diagram:

1. Environment has the highest frequency (6), which means this factor is the main cause of the analyzed problem. It accounts for about 46.15% of the total occurrences.
2. Method is the second most significant factor, with a frequency of 5, which accounts for 38.46% of the total occurrences.
3. Material has the lowest frequency (2), and accounts for 15.38% of the total occurrences. The cumulative line shows that by improving the Environment and Method aspects, about 84.61% of the problems can be solved. Therefore, improvement measures should focus on these two factors to get the most significant results.

Step Five: Repair and Prevention

The repair and prevention methods used to deal with defects in Alumino Thermit Welding (ATW) rail joints were identified.

1. Repair
   Remedial methods that can be used to repair damage to Alumino Thermit Welding (ATW) rail joints:
   a. Patching with electric welding, by adding new welding material, the rail joint surface can be repaired so that it returns to optimal condition.
   b. Grinding, by grinding the joint surface can be made smooth again, which helps to reduce friction and further wear on the rail joint.
   c. In some cases, the damage to the rail joint may be severe enough to require re-welding or re-performance of the Alumino Thermit Welding (ATW) process.
2. Prevention
   Prevention is a key measure to reduce the frequency of defects in ATW rail joints. One of the suggested prevention methods to reduce defects in Alumino Thermit Welding (ATW) rail joints are:
   a. Monitoring guard rail parameters at curves. By monitoring these parameters, the maintenance team can ensure that the guard rail is functioning properly and help

reduce the dynamic load received by the rail joints, thereby reducing the risk of damage.

b. Conduct scheduled maintenance and regular inspection of rail joints. The use of technology such as ultrasonic tests to detect potential cracks before they become more severe is highly recommended.
c. Scheduled rail alignment and flatness checks are an important step in preventing further damage, especially in small curved areas that are prone to high stresses.
d. Dissemination of Recommended Speeds on Curves, it is important to disseminate information to drivers and operators on the recommended speeds when crossing curves. By running trains at the right speed, the dynamic load received by the rail joints can be reduced, thereby reducing the risk of wear and damage.
e. If a defect is found that is close to the tolerance limit, immediate corrective action should be taken to prevent more serious damage from developing.

CONCLUSION

Based on the research results from the Analysis of Thermite Rail Joint Damage In Curve Section 3 of LRT Jakarta, the following conclusions can be drawn:

a. Damage that occurs in Alumino Thermit Welding (ATW) rail joints in the Section 3 Petak Pulomas Station - South Boulevard Station LRT Jakarta line arch is a combination of various types of Surface defects.
b. Damage that occurs in Alumino Thermit Welding (ATW) rail joints in the Section 3 Petak Pulomas Station - South Boulevard Station line arch of the Jakarta LRT is caused by:
   1. The factor causing damage or the largest is environmental factors amounting to 46.15% of the total occurrence.
   2. Inspections carried out only visually and carried out at night in limited lighting conditions are the second most significant cause with a contribution of 38.46%.
   3. Material is the smallest contributing factor, at 15.38%.
c. Improvements should be focused on the Environment and Method aspects. By improving these two factors, about 84.61% of the problem can be solved. The recommendations to overcome and prevent damage to Alumio Thermit Welding rail joints that can be applied, such as:
   1. Use of Electric Welding to repair surface damage that may arise due to wear or deformation of the rail joints.
   2. Grinding is performed to re-level the joint surface that may experience deformation or wear.
   3. Coordination with the Operation Control Center & Unit Crew Leader (Driver) regarding the recommended speed limitation on the Curve, and rechecking the visible distance of the 80 KM/h speed limitation motto (motto 2) By running the train at the right speed, the dynamic load received by the rail joints can be reduced, thus reducing the risk of wear and damage.
   4. Conduct scheduled maintenance and regular inspection of rail joints. The use of technology such as ultrasonic tests to detect potential cracks before they become more severe is highly recommended.

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