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A Review of Reforming Processes in the Railway Manufacturing Industry : Case Study of PT. Industri Kereta Api (Persero)

Stephanus Yosi Kristanta[1], Atik Setyani[1*], Sudaryanto[1], Muhammad Syukron[1], Muji Santoso[2]

[1]Program Studi Teknik Metalurgi, Fakultas Teknologi Mineral, UPN "Veteran" Yogyakarta, Indonesia

[2]PT Industri Kereta Api Persero Madiun, Est Java, Indonesia

*Corresponding author : atik.setyani@upnyk.ac.id

Abstract

The railway manufacturing industry is critical for developing efficient and sustainable mass transportation systems. PT. Industri Kereta Api (Persero) (PT. INKA), a leading company in Indonesia, faces significant challenges due to deformation caused by residual stress during welding processes. This study reviews various reforming techniques implemented by PT. INKA to address these issues. The objectives include evaluating the effectiveness of these techniques and identifying potential improvements. Methods such as post-weld heat treatment (PWHT), controlled cooling, and mechanical tools are analyzed for their ability to mitigate deformation. The study demonstrates that PWHT reduces residual stress and improves material quality by homogenizing the microstructure. Controlled cooling techniques effectively reduce distortion by allowing even temperature distribution during the cooling process. Mechanical tools provide non-thermal methods to stabilize and control deformation, significantly reducing distortion levels. Despite the success of these techniques, PT. INKA faces challenges related to process control and skill variance among workers. The study concludes that while reforming techniques significantly enhance the structural integrity and performance of railway components, consistent implementation and clear guidelines are essential for future improvements. Developing new technologies, enhancing workforce training, and creating comprehensive process guidelines are recommended to maintain high standards and competitiveness in the global market.

Keywords: Railway Manufacturing, Residual Stress, Reforming

Introduction

The railway manufacturing industry plays a crucial role in supporting an efficient and sustainable mass transportation system. One of the prominent companies in Indonesia's industry is PT. Industri Kereta Api (Persero). Since its establishment, PT. INKA (Persero) has faced various challenges and undergone numerous changes to improve the quality of its products and meet international standards. One of the main

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challenges in the railway manufacturing process is deformation caused by residual stress during the welding process (Dong, Pingsha, Song, Shaopin, Zhang, 2014). This residual stress can affect the structural integrity and longevity of the products, necessitating effective reforming techniques to correct the deformation (Kazanjian, 2017).

The reforming process is a technique used to correct deformation and distortion that occur during the welding process by manipulating materials that have undergone residual stress Bandriyana (Bandriyana, 2006). This technique encompasses various methods such as post-weld heat treatment, controlled cooling, and the use of mechanical tools to restore the original shape of deformed components (Arifin, A. & Hendrianto, n.d.). The proper implementation of reforming techniques can enhance the quality and performance of the final product and reduce production costs by minimizing the need for rework or component replacement.

In this study, I will review various reforming techniques that PT has implemented. INKA (Persero). I will evaluate the effectiveness of these techniques in addressing deformation issues caused by residual welding stress. Additionally, I will identify the challenges faced by PT. INKA (Persero) in implementing these techniques and exploring potential improvements that can be made in the future.

Treatment of Reforming Process in Railway

1. Post Weld Heat Treatment

Post Weld Heat Treatment (PWHT) is one of the most widely used treatment methods for stress relief in welded materials. PWHT involves heating the welded parts or the entire welded component to a high temperature and holding it for a certain period of time (Pangesti, 2017). According to (Suharno, Sugiyanto A., 2012), the PWHT process can reduce residual stress in welded materials, decrease the occurrence of damage/cracks, and homogenize the microstructure, thus improving the quality of the material. This is consistent with findings by (Prachya, P., & Poopat, 2015), who stated that the PWHT process could reduce defects due to post-weld hot cracking, lower the risk of corrosion, and increase material toughness. (Kazanjian, 2017) also reported that this method is effective in reducing residual stress in steel structures, thereby enhancing the durability and longevity of the products (Cao, X., Rivaux, B., Jahazi, M., Cuddy, J., Birur, 2009).

2. Controlled Cooling

Controlled cooling involves regulating welded components' temperature and cooling rate to reduce distortion. A study by (Zhang, Y., Liu, X., & Wang, 2019) demonstrated that this technique is highly effective for aluminum materials, which are frequently used in the manufacturing of railway components. The study conducted by (Jhonson, A., 2020) demonstrates that gradual post-weld cooling can reduce residual stresses that lead to distortion. This approach allows metals to cool more evenly, reducing the drastic temperature gradients that often cause significant distortion (Wiryosumarto, H. & Okumura, 2008). Various techniques have been proposed and developed to

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implement controlled cooling. One widely discussed approach is using controlled airflow or other precisely controlled cooling mediums. According to research conducted by (Krebs, J. & Kassner, 2007), adjusting the cooling rate and distribution of the cooling medium can be tailored to the material characteristics of the weld and its geometric configuration to achieve optimal results in reducing distortion (Akella, S., Kumar, B. R., & Krshnaiah, 2013).

3. Use of Mechanical Tools

Various techniques have been developed to control welding distortion, among which is the use of mechanical tools as a nonthermal approach (Iqbal, 2020). According to research by (Oliveira, 2018), mechanical tools' distortion control techniques have shown significant potential in reducing welding-induced distortions. They investigated the use of mechanical support systems capable of stabilizing and controling deformation during the cooling process (Budiman, 2024). Their experimental study relevated that the use of mechanical tools can reduce distortion levels by 30-50% compared to conventional methods without additional control measure (Amirullah, 2018). Specifically, this mechanical tool compries a support system placed around the weld zone to constrain thermal and mechanical movement of the workpece during the cooling process(Sharma, S. D., Saluja, R., & Moeed, 2013). This approach not only reduce distortion but also preserves the dimensional integrity of components after the welding process. In another study conducted by (Khan, 2020), they developed a similar approach using an adjustable mechanical tooling system for relies on the precise design of dynamics involved in the welding process.

Case Study: PT. INKA (Persero)

In PT. INKA (Persero), they employ a technique called reforming to prevent or reduce residual stress resulting from welding processes. This reforming process involves the following steps :

1. Material Heating: The material to be welded is first heated. This heating process is carried out until the material reaches a high temperature or turns red.

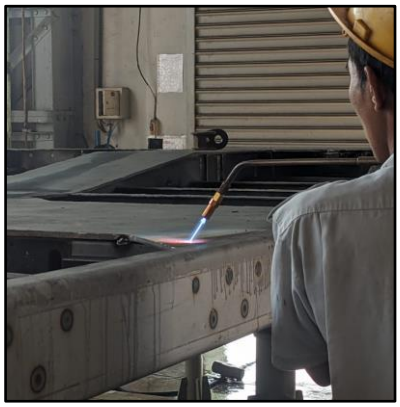

Figure 1. Material Heating

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2. Forging: Once the material reaches the appropriate temperature, the forging process is performed using a hammer. This process aims to restore the material to its original desired dimension and shape. At this stage, mechanical tools like JIG are used to ensure the material dimensions meet the desire specifications.

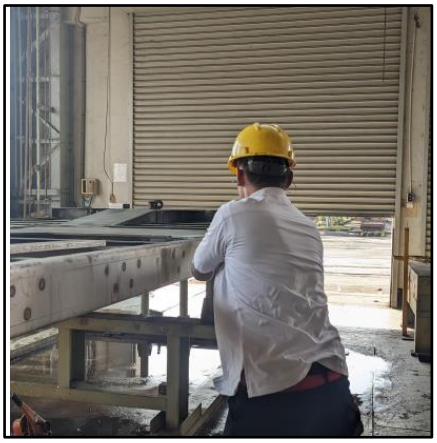

Figure 2. Forging use Hammer

3. Water Cooling: After the forging process and the material dimensions are verified, cooling is conducted using water. Rapid cooling with water aims to reduce residual stress in the welded material.

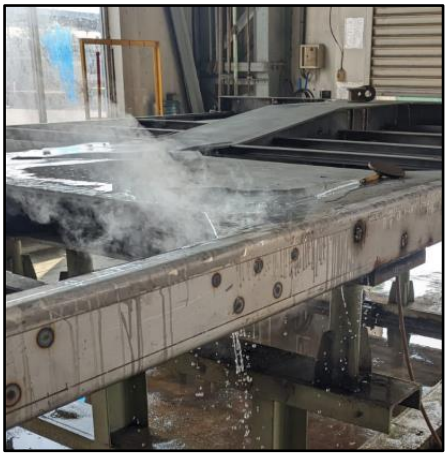

Figure 3. Water Cooling

In addition to these reforming techniques, PT. INKA also utilizes fans or blowers to control cooling during the welding process. This helps maintain stable material temperature and prevents unwanted deformations or residual stresses.

Discussion

The railway manufacturing industry is essential for the development of efficient and sustainable mass transportation systems—companies like PT. Industri Kereta Api (Persero) (PT. INKA). Since its inception, PT. INKA has faced and overcome numerous challenges to enhance product quality and meet international standards. One of the significant challenges in railway manufacturing is deformation caused by residual stress

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during welding processes. This residual stress can compromise railway products' structural integrity and longevity, necessitating effective reforming techniques to mitigate these issues.

Reforming processes are employed to correct deformation and distortion in welded materials by addressing residual stress. Techniques such as Post Weld Heat Treatment (PWHT), controlled cooling, and the use of mechanical tools are pivotal in restoring the original shape and dimensions of deformed components (Kozak, J., & Kowalski, 2015). Proper implementation of these techniques improves the final product's quality and performance and reduces production costs by minimizing rework or component replacement. The success of these techniques in PT. INKA's manufacturing process highlights its importance in maintaining product standards and enhancing production efficiency.

PT. INKA employs an integrative reforming approach, including material heating, forging, and water cooling. Initially, materials are heated to high temperatures to prepare them for welding. Subsequently, forging is performed to restore materials to their original dimensions and shapes, with mechanical tools like jigs ensuring precision. Finally, rapid cooling with water reduces residual stress (Kanga, H. T., Leeb, Y.L., Sun, 2017), controlled cooling using fans or blowers during welding helps maintain stable temperatures and prevent unwanted deformations (Purkuncoro, 2020). These comprehensive reforming techniques have significantly improved the structural integrity and performance of PT. INKA's railway products.

Despite the successes of these reforming techniques, PT. INKA faces challenges related to process control and the need for clear, written guidelines to ensure consistent implementation. Variances in skill levels among workers can lead to inconsistencies in the reforming process, affecting product quality. To address these challenges, PT. INKA must focus on developing new technologies, enhancing workforce training, and creating comprehensive process guidelines. These improvements will help maintain high standards and competitiveness in the global market.

Conclusion

The reforming process plays a crucial role in the railway manufacturing industry, particularly in deformation issues due to residual stresses from welding processes. PT. INKA (Persero) has implemented an integrative approach by combining reheating, forging, and controlled colling, which has proven effective in enhancing the quality and performance of its products. However, challenges in process control and the need for clear written guidelines must be addressed to ensure the future consistency and effectiveness of the reforming techniques. By developing new technologies, enhancing workforce skills, and creating comprehensive process guidelines, PT. INKA (Persero) can continue to improve its competitiveness in the global market.

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