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APPLICATION OF THE FMEA METHOD TO KNOW THE FACTORS CAUSING WELD DEFECTS IN THE BOILER FABRICATION PROCESS

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Abstract- In an era of changing consumer needs and high demand for reliable products, companies need to improve product quality to be able to maintain their business in a competitive industrial world. Including the quality of the boiler as a component of the thermal power plant must be maintained at good performance so that the power plant can operate normally. This study aims to improve the quality of boiler fabrication through the application of the FMEA method. The results showed that the average percentage of weld defects from the results of radiographic testing exceeded the target set by the company for tube-tube, header-header and header-end caps welding joints. Types of welding defects that often occur are porosity welding defects with a percentage of 36%. Based on the data analysis, there are four main factors that influence the welding results, including the ability of the welder, the conditioning of the welding electrode, the parameters of the welding machine, and environmental conditions. Methods: This study aims to determine the factors that cause welding defects in the boiler fabrication process in a power plant component company. The type and design of the research carried out is quantitative research with case studies. From the results of data processing regarding the defect rate, the research focused on the results of radiographic testing that exceeded the company's target. The result was that the type of defect with the highest percentage was porosity of 35.8% or around 36%. That is, most of the welding defects that cause failure in the welding results are the occurrence of weld porosity. Meanwhile, for other types of welding defects, the percentage is below 30%. Based on the results of data collection and analysis, it can be concluded as follows: the dominant type of weld defect in boiler fabrication from radiographic test results is porosity weld defect, the main causes of porosity welding defects include the ability of the welder, not conditioning the electrode/welding wire, welding machine parameters, and environmental conditioning. Quality improvements include, among others, the welder by holding training and testing the WPQ (Welding Performance Qualification) again for each project, performing treatment on the welding wire, supervising the setting of the welding machine parameters, and covering the welding area with cloth or tarpaulin so that the welding area is free from wind. and other environmental conditioning.

Keywords: FMEA, Boiler, Weld Defects, Radiography Test

1. INTRODUCTION

The growth of the industrial world, including the manufacture of components for power plants, is currently growing rapidly. This is related to the increase in world energy demand in 2019-2035 which is expected to increase along with the development of the industrial and service sectors and changes in social life (Global Industry Analysis, 2016). In Indonesia, based on the Decree of the Minister of Energy and Mineral Resources (Energy and Mineral Resources) No. 1567 K/21/MEM/2018, the government plans to increase the target capacity of PLN and IPP as BUMN (State Owned Enterprises) engaged in the energy and electricity sector in Indonesia to 106 GW with plans to build power plants of 56 GW (ESDM, 2018). The composition of power plants that can meet most of the demand for electricity is PLTU of 37% of the total increase in energy required. The rest, the need for electric power is obtained from other energy sources. PLTU is a type of thermal power plant that is widely used because of its high efficiency so that it produces economical electrical energy. PLTU consists of main components and auxiliary components (support systems) as well as other systems. The main components of PLTU consist of four parts, namely Boiler (Pressure Parts), Turbine, Condenser, and Generator. Boiler is a power plant component that functions to change the supply of water fluid into steam with high pressure and temperature. The process of change occurs by heating the water in the tube boiler on an ongoing basis. The steam produced will then flow into the turbine to drive the generator so that electrical energy is produced. This shows that the performance of the boiler affects the operational conditions and efficiency of the power plant. Therefore, this research will discuss further about the boiler fabrication process (Khatammi and Wasiur 2022).

A. *FMEA method*

FMEA (Failure Mode and Effect Analysis) is a structured procedure to identify and prevent as many failure modes as possible (Ford Motor Company 2011). FMEA is used to identify the sources and root causes of a quality problem. FMEA is a systematic approach to risk analysis, definition, budgeting and assessment that includes identification and analysis of: (1) all failure modes of different parts of the system, (2) the effect of these failure modes on the system (3) how to avoid failure and/or moderate the effects of a failed system (Putra and Purba, 2018). FMEA has a measurement method that is reviewed from three perspectives, namely: Severity (S), Occurrence (O), Detection (D) (Chin et al., 2008). The FMEA evaluation system gives a score between 1 and 10 where 1 is the best score and 10 is the worst score for each of the three perspectives. By multiplying the values for the Severity (S) Occurence (O) and detection (D) levels the decision making team calculates the Risk Prioriry Number (RPN), $RPN = S \times O \times D$, higher RPN values are considered more important and will be given higher priority for improvement. Not all RPN values must be corrected, but by looking at the critical values it will be known which RPN needs corrective action, the determination of critical RPN is as follows, CRITICAL RPN = $=\sum RPN / \sum$ Risk (Suryani, 2018). RPN helps the decision-making team detect parts or processes, which require priority actions for proper improvement, but the final decision depends entirely on company policy (Shariati, 2014).

B. *Welding Process*

Welding is the joining of two or more materials based on the principles of the diffusion process, resulting in the joining of the parts of the materials being joined (Fariya, 2014). The advantages of welded joints are lightweight construction, can withstand high strength, easy to implement, and quite economical. However, the main weakness is the change in the microstructure of the material being welded, resulting in a change in the physical and mechanical properties of the material being welded. The common method used to heat the metal being welded is an electric current (Stamatis 2015). Electric current is generated by a generator and flowed through a cable to a device that clamps an electrode at the end, which is a metal bar that conducts electricity well. When an electric current is applied, the electrode is touched to the workpiece and then pulled back a little, the electric current continues to flow through the narrow gap between the tip of the electrode and the workpiece. This flowing current is called an arc that can melt metal. Based on the classification of how it works, welding is divided into three main classes, namely liquid, compressive, and soldering welding (Heri, 2008). Liquid welding is a method of welding in which the joint is heated to a point with a heat source from an electric arc or some kind of burning gas flame. In press welding, a method of welding in which the joint is heated and then pressed together (Khatammi and Wasiur 2022). While soldering means a method of welding in which the joints are bonded and put together using a metal alloy that has a low melting point.

a) Shielded Metal Arc Welding
SMAW/Stick Welding is an electric arc welding process in which the connection is produced by heating with an electric arc between the covered electrode and the work piece. The shield is obtained from the decomposition of the wrapped electrodes. Pressure is not applied and filler

metal comes from the electrodes. Normally the method for implementing SMAW is manually. The percentage of this method in its use reaches 99%. Semi-automatic and machine methods are not used. An automated method is used and is also called gravity welding but has very limited use.

b) Gas Metal Arc Welding (GMAW)
GMAW is an electric arc welding process that produces a metal joint by heating the metal using an electric arc between the filler metal of the consumed electrode and the work piece. Arc protection and metal welding using gas or gas mixtures. This process is also known as MIG welding. The electrode wire in the GMAW process is fed continuously to the electric arc so that weld metal deposits are formed.

c) Flux Cored Arc Welding
FCAW is an electric arc welding process that produces a metal joint by heating the metal using an electric arc between the filler metal of the consumed electrode and the work piece. Apart from being obtained from gas, the shield also comes from the flux contained in the electrode core. Therefore shielding gas can be used or not. This process is used in steel welding and is normally carried out semi-automatically (automatically feeding the welding wire).

d) Gas Tungsten Arc Welding (TIG Welding)
GTAW is an electric arc welding process that produces metal joints by applying heat from an electric arc between a tungsten electrode and the workpiece. GTAW is also known as Tungsten Inert Gas (TIG) welding. GTAW is used to perform high quality welding in various fields such as nuclear, aviation, and food industry.

e) Submerged Arc Welding (SAW)
SAW is an electric arc welding process that produces a metal joint by heating the metal using an electric arc between the electrode metal and the workpiece. The electric arc is protected by flux material covering the arc. SAW is used automatically and is limited to hand-down and horizontal positions. A popular method is to use a machine where the operator monitors the operation of the weld. The second popular method is the automatic method where welding is done by pressing a button on the machine. This process can also be used with semi-automatic machines, but this use is not very popular. This process cannot be used manually because it is impossible for the welder to control flames which cannot be seen.

C. Welding Defect Test Method

Welding defects can be interpreted as a defect in the welding due to the absence of continuity at the welding joint. The discontinuity of the welds at the welded joint can be due to a reason in the welding process, such as the lack of homogeneity of the mechanical, metallurgical and physical properties of the material. There are several standards that provide a definition of a weld defect. By referring to existing standards, welding defects can be divided into 2, namely defects in the weld area including the HAZ (Heat Affective Zone) and defects outside the area of the weld material. To find out and detect the presence of various forms of these defects, there are 5 of the most commonly used methods, such as VT (Visual Test), MT (Magnetic Test), PT (Penetran Test), RT (Radiographic Test), and Ultrasonic test (UT).

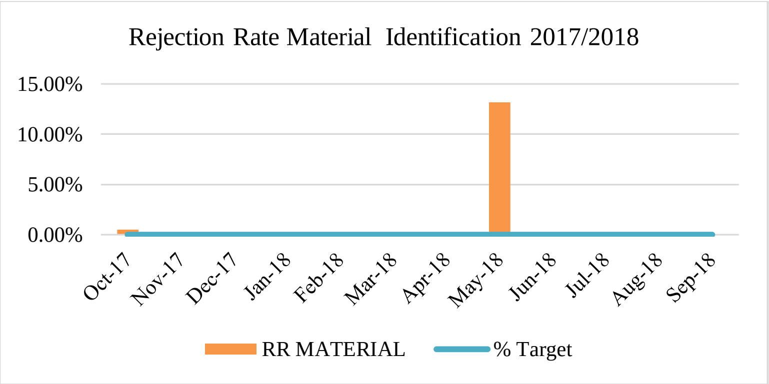
2. METHOD

A. Type of Research

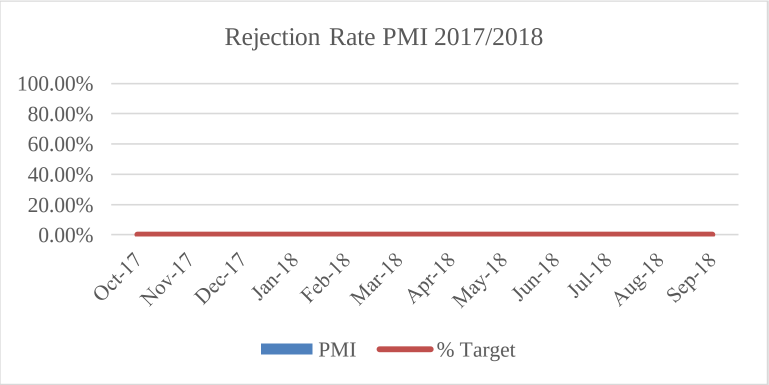
This study aims to determine the factors that cause welding defects in the boiler fabrication process in a power plant component company. The type and design of the research carried out is quantitative research with case studies.

3. RESULTS AND DISCUSSION

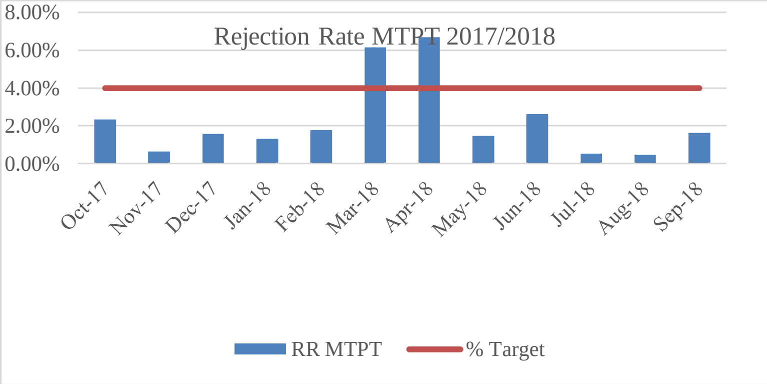
Picture 1. Rejection Rate Material Identifikation Boiler 2017/2018



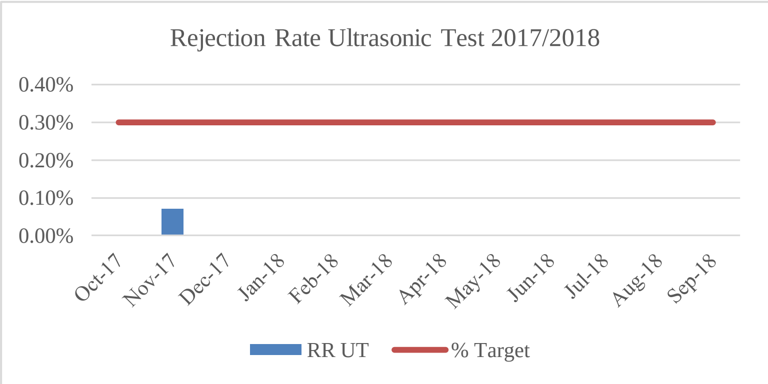
Picture 2. Rejection Rate PMI Boiler Testing 2017/2018



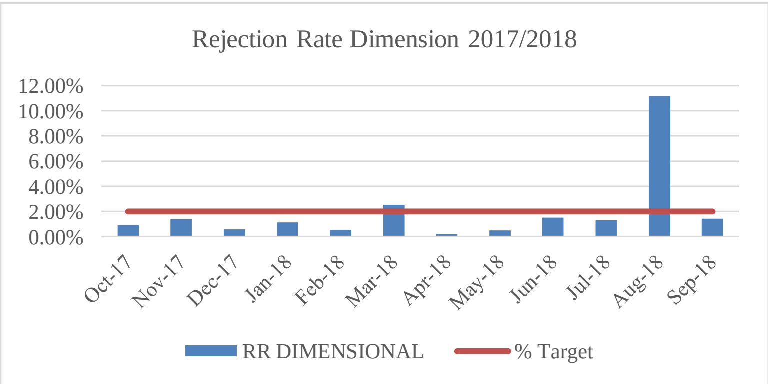
Picture 3. Rejection Rate MTPT Boiler 2017/2018



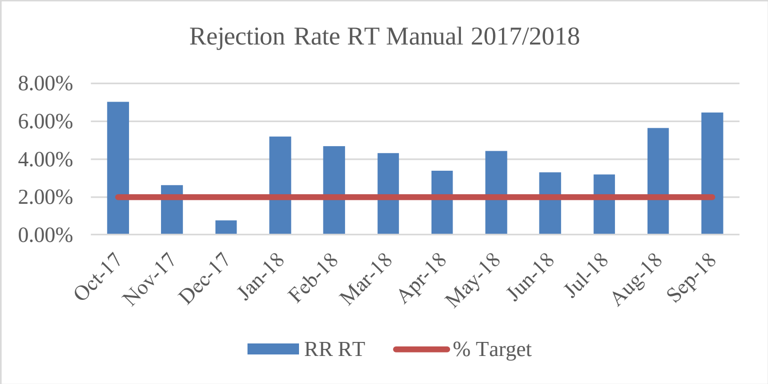
Picture 4. Rejection Rate UT Boiler 2017/2018



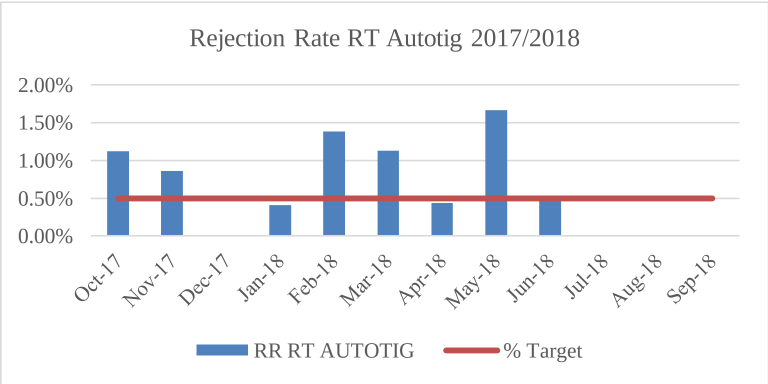
Picture 5. Rejection Rate Dimention Boiler 2017/2018



Picture 6. Rejection Rate RT Boiler 2017/2018



Picture 7. *Rejection Rate* RT *Autotig Boiler* 2017/2018



Based on Figures 4.1 – 4.7, the percentage rejection rate has a different value each month. Rejection Rate (RR) data consists of RR Material, RR PMI (Positive Material Inspection), RR Endoscope, RR MT (Magnetic Test) & PT (Penetrant Test), RR UT (Ultrasonic Test), RR RT (Radiography Test) Manual, and RR RT (Radiography Test) Autotig. Each type of test/inspection has a different target rejection rate. Target rejection rate Identification Material 1.14%, PMI 0%, MTPT 4%, UT 0.3%, Dimensional 2%, RT Manual 2% and Autotig 0.5%. In Figure 4.1, RR Material Identification with a percentage exceeding the company's target occurred in October 2017 and May 2018. Material identification was carried out before and during the fabrication process. Material identification inspections include specification and size identification errors, material order list errors, identification transfer errors, hard-stamp errors, and incomplete hard-stamps. Based on inspections in the field, the errors that occurred in that period were identification transfer errors (Kusmayadi and Vikaliana 2021).

For PMI and UT testing inspections (Figures 4.2 and 4.4), for 1 year no errors were found that exceeded the predetermined target rejection rate. Meanwhile, for the inspection of other welding results by means of MT-PT, dimensions, and radiography (Figures 4.3, 4.5, 4.6, 4.7) it can be seen that in certain months the percentage of rejection rates obtained exceeds the company's target.

To simplify the analysis, Figure 4.8 shows the average rejection rate for 1 year. In Figure 4.8, it is found that the average rejection rate that exceeds the target rejection rate includes RR Material Identification, RR RT (Manual), and RR RT Autotig. This study focuses on RR RT (Manual). This is because material identification does not involve the welding process and each material that is welded is already in identified condition according to the procedure and for RR RT Autotig an average percentage is still close to the target. The definition of manual is used to show that the joint tube process is carried out using an automatic machine/autotig machine. It's different with RR RT (Manual), where the joint tube process is done manually by the welder.

4. DISCUSSION

By knowing the research focus, the next step is to analyze and process data using the FMEA method to reduce welding defects from the results of radiographic testing and improvement plans to reduce welding defects in the boiler fabrication process. By knowing the types of welding defects produced by the production department, the company can focus on identifying the types of welding defects that occur the most or have the greatest contribution to the problem. What customers want will be easily achieved and right on target (Ford Motor Company 2011).

From the results of data processing regarding the defect rate, the research focuses on radiographic test results that exceed the company's target. The types of defects identified using radiographic testing include porosity, internal concavity, debris, slag inclusion, incomplete fusion, incomplete penetration, crack, root undercut, tungsten inclusion, and excess. The types of defects that become CTQ (Critical to Quality) in this study are depicted using a Pareto diagram. Figure 4.9 shows a pareto diagram of the average percentage of each type of defect produced in radiographic testing. The result shows that the type of defect with the highest percentage is porosity of 35.8% or around 36%. That is, most of the welding defects that cause failure in the welding results are the occurrence of weld porosity . Meanwhile, for other types of welding defects, the percentage is below 30%.

The next stage is the stage using the FMEA method. FMEA (Failure Mode and Effect Analysis) is a structured procedure to identify and prevent as many failure modes as possible. FMEA is used to identify the sources and root causes of a quality problem (Ismawati Khotimah, Hagni Wijayanti, and Sri Setyaningsih 2021).

Making FMEA is done with the aim of analyzing potential process failures and evaluating these failures. Every time a defect or damage occurs, the RPN value is sought, then the RPN value is arranged from the largest value. This is the main cause of the problems encountered. The RPN value is obtained by multiplying the severity, occurrence, and detection values of each problem. RPN is a criticality indicator for determining appropriate failure-mode corrective actions. RPN is used to estimate risk using the following three criteria:

1. Severity of effect (severity) S- how serious is the final effect?
2. Occurrence O – how the cause occurred and the result in the failure mode
3. Detection of causes (detection) D – how can failures or causes be detected before they reach the customer

Filling in the FMEA Table is carried out by way of discussion by the production manager, Technology Group (TG) supervisor, QC manager, QA manager, and Third Party Inspector/Qualified Inspector to determine severity, occurrence, and detection values. Assessment of the FMEA indicators and recapitulation of the FMEA results can be seen in the table below with an explanation of the various failure modes, consequences of failure, causes of failure and corrective corrective actions that need to be taken.

5. CONCLUSION

Based on the results of data collection and analysis, it can be concluded as follows: the dominant type of welding defects in boiler fabrication from the results of radiographic testing is porosity welding defects, the main causes of porosity welding defects include the ability of the welder, not conditioning the electrode/welding wire, machine parameters welding, and environmental conditioning. Quality improvements include, among others, the welder by holding training and testing the WPQ (Welding Performance Qualification) again for each project, performing treatment on the welding wire, supervising the setting of the welding machine parameters, and covering the welding area with cloth or tarpaulin so that the welding area is free from wind. and other environmental conditioning.

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