STUDY OF COMPONENT SAFETY LEVEL (RELIABILITY) IN STEAM BOILER

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ABSTRACT. Every steam power plant has problems in operation, especially problems related to the reliability of components in the boiler system because of the presence of random technical (operator negligence), technological and statistical errors (poor maintenance). This study aimed to measure the reliability of the boiler components. This research study is focused on steam boilers at the Mechanical Engineering Plant Laboratory at Ungku Omar Polytechnic, Ipoh. The risk assessment of components failure is carried out using Event Tree and Fault Tree probability methods to predict the life of the boiler and ensure the system is always in a safe state. Quantitative methods use Microsoft Excel software for manual calculations and Reliasoft BlockSim 7 software for qualitative evaluation methods for this system. Identifying the meantime between failures is necessary, reducing factors in situations where exploitative parameters are within the normal limits. From the results of the study on the components of the boiler, it was found that the reliability of the Low Water Alarm component was 95.7%, Gauge Glass 18.3%, Safety Valve 97.8%, Main Stop Valve 97.8%, Pressure Gauge 65.7%, and Low Water Fuel Cut-off Device 32.0%. The overall reliability of the boiler system is 86.6%. The steam boiler is still in a safe condition to operate. The results can be used to improve preventive maintenance systems and choose the most reliable operation performance.

KEYWORDS: Life expectancy; probability; predictability; safety; boiler

1 INTRODUCTION

There are human activities which present risks for life, property, and the environment. The amount of danger has increased along with technological advancement, and in some situations, even the design and functionality of the most recent system cannot ensure the safety of workers and equipment. Workplace procedures have been significantly impacted by industry efforts to prevent accidents. Every steam power plant system encounter problem during operation, both directly and indirectly. These problems occur due to the exclusion of operators and poor maintenance (Ali Nouri et al., 2017).

The operation of the steam boiler system on the components of the boiler is studied conceding hope to ensure that the boiler reaches the proper reliability. Among the problems that arise in this system are the safety valve which is not working properly i.e., the pressure cannot reach the required level for the power plant to operate until the efficiency of the plant to operate, the water level is unstable where the water cannot be adequately channelled to the boiler during the operating time. The system is also exposed to hazards such as exploding, burning, toxic gas leaks and so on (Min et al., 2017). Aspects of care for boiler components such as safety valve, water treatment, temperature shock, pressure gauge, low water level stop device are among the main causes of boiler failure. Boilers often fail because of incidents such as water problems, rust, and so on. Environmental parameters influence steam boiler system dependability, influencing the dimensioning of component support and its evaluation and forecasting to achieve efficiency and cost effectiveness (Yulianto et al., 2021). Integrating environmental parameters in reliability analysis is a powerful tool for forecasting services, repairs, and spare parts. Reliability is a function of time/load and the operating environment of a product, which includes factors such as the surrounding environment, condition-indicating parameters, and human aspects (Arwa et al., 2021, Moneim et al., 2019). Covariates are related to these factors. Figure 1 shows the main components found in a steam boiler.

Figure 1: Main Components of Steam Boiler

1.1 Probability Theory

Shouri and Sreejith (2008) stated that equipment that fails to function in the plant occurs because of the interaction between the components of the equipment. For component failure in each time interval is referred to as the average failure rate, γ (failure/time). As for the probability for a component that does not fail, it is referred to as reliability and is given by Weilbull:

$$R(t) = e^{-\gamma t} \tag{1}$$

As for the probability of failure, *P* is given as:

$$P(t) = 1 - R(t) = 1 - e^{-\gamma t} \tag{2}$$

The probability density function is defined as a derivative of *P(t)*:

$$f(t) = \frac{dP(t)}{dt} = \mu e^{-\mu} \tag{3}$$

The failure density function is used to determine the probability value, *P* that the component has a malfunction in the time interval $t_0 \rightarrow t_1$

$$P(t_{0-}\ t_1) = \int_0^1 f(t)dt = \mu \int_{t_0}^{t_1} \mu e^{-\mu t}dt = e^{-\mu to} - e^{-\mu t1} \tag{4}$$

This integral illustrates the breadth between the failure density function and the time interval between the two component failures called the average time between failures (*Mean Time Between Failure*, MTBF):

$$E(t) = MTBF = \int_{t_0}^{\infty} tf(t) = \frac{1}{\mu} \tag{5}$$

The safety of the boiler's operation depends on many factors such as the design and technology of the components, the working conditions, and the mode of operation by the operator and the maintenance of the power plant. The safety aspects of the operational safety process of a component that can lead to injury and property damage are related to exceptional situations where they occur in a rapid period and are also known as *acute* problems (Tynchenko et al., 2019). For that, a workplace security system is developed. This system emphasizes design, construction, and operation to reduce the occurrence of dangerous incidents. The design and failure of the pressure mechanism on the components used in the boiler system is thoroughly reviewed to determine how these components can be improved for the service life of the components, reduce maintenance, and improve reliability (Jang et al., 2003). This study was to assess the reliability of the main components of safety on the steam boiler by stunning the probability method of *Fault* Tree and *Events Tree* in *the Reliasoft BlockSim 7* software.

2 METHODOLOGY

In quantitative analysis of probabilities, the dangers will be assessed using *the Failure Tree. Fault tree* analysis (FTA) is a technique in which most of the events that occur can be attributed to a logical hierarchy in which indicates that some system failure will appear. Failure data for various recorded components are provided in the table according to the period of operation. While the analysis of maintenance record results for Reliability and Probability uses the *Weilbull* equation in Excel. The forecast module in the *ReliaSoft Block Sim 7* Software enables predicting the failure rate for a set of components in each or specified state. All methods of forecasting the failure rate have the same general form. This predictive module provides the user with a high visual interface which allows the user to select the components, determining the conditions of how they operate such as temperature, high pressure or environmental conditions. This forecasting software automatically performs the calculation of the failure rate as defined according to the standard and subsequently prepares the results. All data collected comes from the boiler's and components' monthly and annual maintenance records (Figure 2).

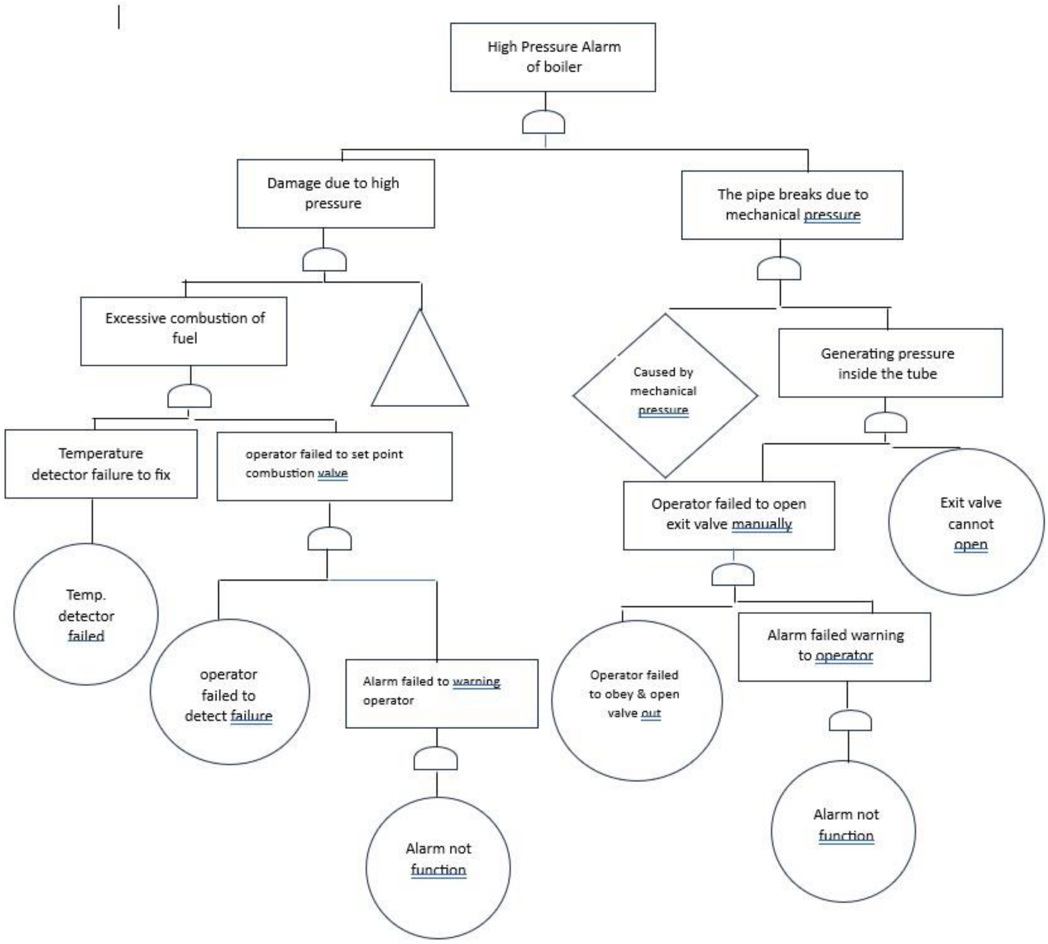

Figure 2: Fault tree and Event tree analysis for boiler maintenance.

3 RESULTS AND DISCUSSION

Figure 3 is a graph of the probability of survival against the maintenance time cycle from the analysis of maintenance record results for *reliability* and *probability* using the Weilbull equation in Excel. This graph shows the capacity rate of the boiler during its usage period. The longer it is used, the lower the rate of cycle maintenance.

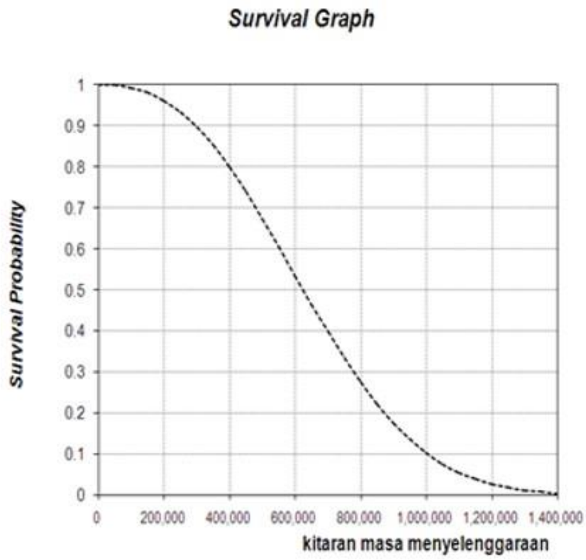

Figure 3: Graph Survival of Probability against time cycles maintenance.

Time cycles maintenance

Figure 4 *Fault tree* analysis shows the results of superheat events using this software to obtain probability and expectation predictions for each boiler component. From Faults tree result, Event tree can construction and evaluation in analyzing accident each component and boiler.

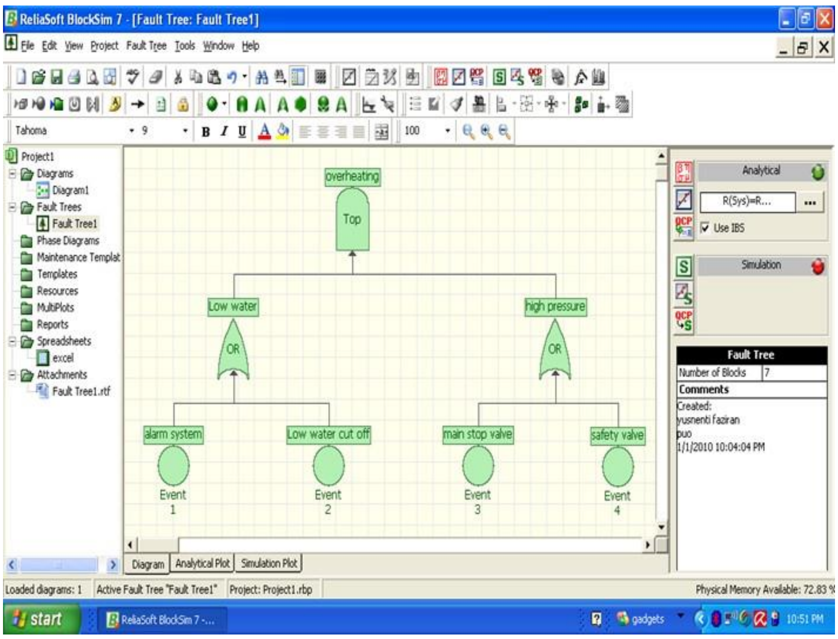

Figure 4: Fault tree analysis for superheat events

The analysis of *the results of Event tree* for high pressure events is as shown in Figure 5 below. The difference for *Event tree* is in terms of its construction and evaluation in analyzing accident sets.

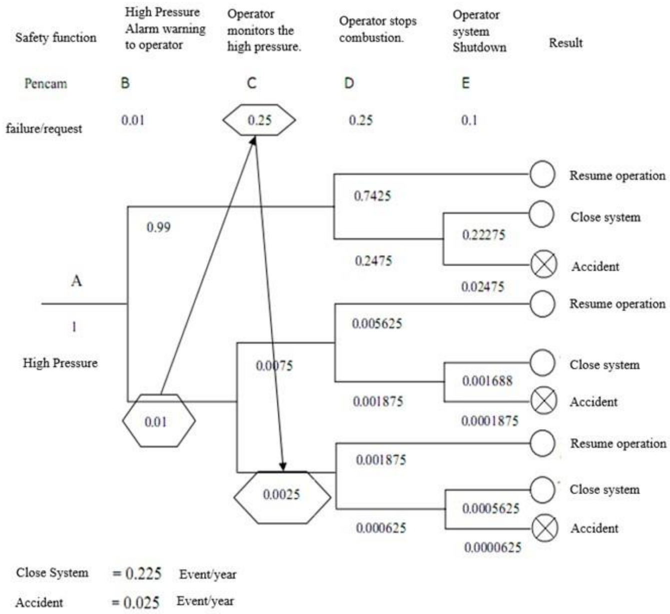

Figure 5: Event tree for high pressure events

Based on the study's findings in Figure 5, in the case of a high-pressure incident/events, the high-pressure control monitor operator reported a system failure. There were 0.25 occurrences resulting in 0.01 incidents of reported failure and 0.0025 failure events if the system was not closed, with a mean time to failure of 0.000625 accidents or failures/years. As a result, this accident occurred below the minimum acceptable failure rate of 0.023 incidents per year. The forecast module in the *ReliaSoft Block Sim 7 Software* enables predicting the failure rate for a set of components in each or specified state. This Module forecast allows the user to select the component, determine the conditions of how it operates such as temperature or environmental conditions. This forecasting software automatically performs the calculation of the failure rate and subsequently prepares the results.

Table 1 shows the probability and reliability data for the components of boiler throughout the operation of the boiler of this software. Where studies are made based on the important components in the boiler. From the results of the study on the components of the boiler, it was found that the reliability of the Low Water Alarm component was 95.7%, Gauge Glass 18.3%, Safety Valve 97.8%, Main Stop Valve 97.8%, Pressure Gauge 65.7%, and Low Water Fuel Cut-off Device 32.0%.

From the analytical evaluation carried out on the boiler maintenance record, it was found that the reliability for the overall operation of the boiler was 86.67%. Table 1 is also the result of probability data analysis and reliability for the components of the boiler throughout the operation of the boiler.

Table 1: Probability Data and Reliability for Boiler Steam component

Component	**γ [failure/year]**	**R, Reliability = $1\gamma t$**	**P, Probability = 1-R**
LOW WATER ALARM	0.044	0.043	0.043
GAUGE GLASS	1.700	0.183	0.817
SAFETY VALVE	0.022	0.978	0.022
MAIN STOP VALVE	0.022	0.978	0.022
PRESSURE GAUGE	0.420	0.657	0.433
LOW WATER FUEL CUT-OFF	1.140	0.320	0.680

Fault tree is an analysis or evaluation technique used to identify the causes of problems that arise by placing the consequences as headlines while for *Event tree*, the causes first need to be identified. These analyses are a series of systematic processes used to know what needs to be achieved to secure any physical facilities (Sohn et al., 2004).

Through the application of these two techniques, every maintenance work can be done well because, through this method, all forms of negligence can be controlled from time to time by taking appropriate action. With this regulation, the life expectancy of a system can be enhanced for the use of instructors and students in learning more effectively for a long period of time. To obtain a risk assessment of the Reliasoft BlockSim 7 software, component failure was used to predict the lifespan of the boiler to ensure that the system is always in a safe condition through maintenance.

4 CONCLUSION

For the reliability assessment of steam boilers at the Plant Laboratory, Ungku Omar Polytechnic, it was found that the overall reliability of steam boilers was still high at 86.6%. It was found that the reliability of the Low Water Alarm component was 95.7%, Gauge Glass 18.3%, Safety Valve 97.8%, Main Stop Valve 97.8%, Pressure Gauge 65.7%, and Low Water Fuel Cut-off Device 32.0%. This is because the plant used is only for demonstration in students and operates only if there are practical classes conducted. Overall, the steam boiler is still in safe condition to use and to help supervisors prepare to ensure maintenance of equipment can be done (preventive maintenance) before failure occurs using this software.

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