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Application of failure mode effect analysis on hazard identification and risk control

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ABSTRACT

Introduction: PT. X is a chemical industry with high hazards, especially those related to hazardous and toxic materials; the company also uses equipment and machines with fire or explosion hazards. Component's failure to operate is a major problem in PT. X. The specific objective of this study was to evaluate hazards and control the risks to prevent accidents and protect company assets, especially for employee safety.

Methods: The data collected is Process Flow Diagram (PFD), Material Safety Data Sheet (MSDS), and component failure data. The risk assessment for the components of Sodium Silicate Production is carried out by multiplying the occurrence measurement scale and severity measurement scale. The risk value for the unacceptable risk category is between 12 and 25, where the risk must be controlled first.

Results: This study found that the highest risk value is dissolver tank leaks, the production pump not working, and the ball valve stuck. An example of structural mitigation in the dissolver tank is to carry out routine maintenance once a month to know the material's condition and to immediately make repairs if there are signs of tank damage to prevent leakage in the tank.

Conclusions: This research proves that some hazards have not been evaluated and controlled, so there are still some failures in the production process of Sodium Silicate.

Keywords: Failure Mode Effect Analysis, Hazard Identification, Risk.
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INTRODUCTION

PT. X is a company engaged in the basic chemical industry, where one of its products is Sodium Silicate. PT. X is a chemical industry prone to danger, especially regarding hazardous and toxic materials. The company also uses equipment and machines with a fire or explosion hazard in its sodium silicate production unit. If various hazards are not identified and handled properly, they can hinder the achievement of company goals and result in unwanted risks.[1,2]

According to law No. 1 of 1970 concerning Occupational Safety Article 3, one of the requirements for work safety is to prevent and reduce accidents, extinguish fires, prevent and reduce explosion hazards, and improve security in jobs with potential hazards.[3] This regulation is one of the basic requirements for risk control efforts for all industries with potential hazards. The production process of Sodium Silicate has a high potential for danger because it uses and produces chemicals, in addition to using equipment and machines that have the potential for fire and explosion hazards. Every system component of the machine is interconnected with each other. If a work failure occurs in one of the systems in carrying out its functions, the Sodium Silicate production process can be stopped. The specific objective of this study was to identify hazards and control risks to prevent unwanted accidents, as well as protect company assets, especially employee safety.

Components' failure to operate is a major problem in PT. X. Based on the failure data of Sodium Silicate Production PT. X found several failures in sodium silicate production during the last three years. In early 2020, there was an explosion in evaporator tank number 8, while in 2019, there was an explosion in the filter press. Previously in 2008, there was also an explosion in evaporator tank 1. For this reason, researchers identified hazards in the Sodium Silicate Production unit using the Failure Mode Effect and Analysis (FMEA) method.[4] FMEA is a method that can analyze forms of failure, causes components to fail to operate, analyze the consequences of failure, and perform risk assessments.[5] After knowing the cause of the failure, it is followed by providing recommendations for prevention and control measures.[6]

METHODS

Study Design

This study used a mixed-method including primary data collected through interviews and secondary data collected through documents and data.

Data Collection

The data collection stage is where data collection related to the problems obtained will be carried out. The data was collected in the form of primary data and secondary data. The primary data was collected through interviews with engineers regarding the operation process in the Sodium Silicate Production unit. Interviews were also conducted with the operator and supervisor of the SSP unit. Operators and supervisors also review the operating abnormality table and maintenance activities for the secondary data obtained by Process Flow Diagrams (PFD), Material Safety Data Sheets (MSDS), component failure data, and other documents support writing.

Determination of problems in equipment, facility, or system is done by sorting out the parts of the equipment, facility, or system so that the discussion can be more focused. The implementation of the review is carried out on the FMEA worksheet. In the identification column, fill in the equipment data to be identified. Getting to the failure mode is through operating experience and asking the person in charge of the maintenance of that component, while getting the failure mechanism may result in the failure mode that has been identified. The effects of failure include three things: local, system, and plant. Local effects consist of the impact of failure on the component and other components still in the subsystem, for system effects including how the impact of failure on other subsystems and the main system, and plant effects, namely how the impact of the main failure on the identified plant. For each failure mode, the effect must be filled in the effect column in the FMEA worksheet.

Data analysis

Before identifying a plant or system, it is interpreted in advance in a Functional Block Diagram, which shows the relationship between the components that make up the system. FMEA is the next step after mapping the functional block diagram (FBD).

The risk assessment for the components of Sodium Silicate Production is carried out by multiplying the occurrence measurement scale and severity measurement scale. The risk value for the unacceptable risk category is between 12 and 25, where the risk must be controlled first.

RESULTS

Failure Mode and Effect Analysis (FMEA) is used to identify the design process and potential failures before they occur to eliminate or minimize the associated risks. This analysis is the next step after mapping the functional block diagram (FBD). In the FMEA analysis of this study, the review was implemented by interviewing the operator and supervisor of the SSP unit, along with a review of the operating abnormality table and maintenance activities.

The risk assessment for each component is carried out by determining the occurrence measurement scale and severity measurement scale, where the formula is as follows:

Risk = Occurrence x Severity

The risk value for the unacceptable risk category is between 12 and 25, where the risk must be controlled first. The following is Table 1 FMEA Sodium Silicate Production.

The table shows that the highest risk value is dissolver tank leaks, the production pump not working, and the ball valve stuck. The leak of the dissolver tank has a risk value of 15, the production pump cannot operate as a risk value of 20, the production pump is not working, and the ball valve jammed has a risk value of 15.

DISCUSSION

Structural mitigation is a recommendation to reduce or avoid accidents or system failures by protecting against hazards that arise. Structural mitigation measures are in the form of technology (safety devices and equipment), maintenance equipment (maintenance equipment), and other recommendations that are directly related to objects or tools. The preparation of structural mitigation uses the results of the FMEA analysis as a consideration.

Structural Mitigation on Dissolver Tank Material

The dissolver tank is a tank for the main process of melting the cullet in the form of lumps into liquid sodium silicate with a very high temperature produced by steam. Based on the risk assessment in the FMEA analysis, the tank component has a fairly small possibility of leakage. However, the impact is very large. Structural mitigations for the dissolver tank are:

a) Perform routine maintenance once a month on the dissolver tank on a regular and scheduled basis to know the condition of the material and can immediately make repairs if there are signs of tank damage so that there is no leakage in the tank
b) To prevent a decrease in the ability of tank materials such as corrosion tanks and reduced tank strength, actions such as painting the tank lining and tank maintenance when the plant is shut down and testing the tank as a pressure vessel at least once every five years following Permenakertrans No.01/MEN/1982.

Structural Mitigation on Production Pumps

A pump is a tool that serves to move or transfer sodium silicate. Based on the risk assessment carried out in the FMEA analysis, the production pump is possibly damaging and can interfere with the production process. Structural mitigations on the pump are:

a) Perform periodic maintenance of pump components to prevent the pump from being damaged quickly.
b) Install a safety device (Thermal Protector) on the pump to avoid fatal damage such as burning, tripping, or overheating the motor body.
c) Replace pump components that have exceeded the limit of use (lifetime) so that the pump is not easily damaged and can save time for repairs.

Structural Mitigation on Ball Valve

The ball valve is a valve or valve with a flow controller that is round like a ball. The ball has a hole in the middle so that the flow will occur when the hole is in a straight line or line with both ends of the valve. However, when the valve has closed, the position of the orifice is perpendicular to the valve tip, and the flow will be blocked or blocked. Based on the risk assessment in the FMEA analysis, the Ball valve component has a fairly small chance of failure. Structural mitigation on Ball Valve:

a) The implementation of preventive maintenance needs to be carried out

Table 1. **FMEA of Sodium Silicate Production.**

No.	Item Description		Description of Failure		Effect of Failure	O	S	R
	Component	Functional Failure	Failure Mode	Failure Mechanism				
1	Gate Valve	The gate valve cannot open and close the flow of sodium silicate	The top of the gate valve is leaking	The top of the valve has exceeded its lifetime	Sodium silicate is released into the environment and then causes pollution and endangers workers	3	3	9
			Worn valve packing	Corrosive due to chemicals	Damaged packing causes other components of the valve to be damaged	3	4	12
2	Dissolver	The dissolver failed to melt the cullet into sodium silicate	The soldered wall is cracked	The presence of corrosion on the soldered wall	Sodium silicate is released into the environment and then causes pollution and endangers workers	3	5	15
			Leak in the utility hole	Closing the utility hole is not tight enough		2	5	10
3	Ball Valve	The ball valve cannot control the inflow	Ball valve stuck	Corrosive due to chemicals	Disrupting the production line so that production is hampered	3	5	15
4	Pressure Gauge	The pressure Gauge failed to measure excess pressure in the production tank	Worn sock drat	Corrosive due to chemicals	Leaking, sodium silicate is released into the environment, causing pollution	3	4	12
			The pressure gauge is broken	Broken spring	Can cause an explosion of the tank due to unknown pressure during overpressure	2	3	6
5	Safety Valve	The safety valve fails to secure when overpressure	The safety valve fails to open when subjected to overpressure	Corrosive due to chemicals	Overpressure may result in an explosion of the dissolver	2	5	10
			System leak on the safety valve	Safety valve spring worn/soft		2	5	10
6	Settling Tank	The tank cannot maintain the volume of sodium silicate stored in it	The tank wall has a leak	There is corrosion on the tank walls	Sodium silicate is released into the environment and causes pollution, and endangers workers	2	5	10
			Leak in the connection pipe connected to the tank	Welding joints are not strong enough		2	5	10
7	Indicator Level	Cannot show the level of sodium silicate in the tank	The indicator sling is broken	The indicator sling is broken	If in high-level conditions, sodium silicate will spill from the tank and cause environmental pollution	3	3	9
			Corrosive indicator wheel	The indicator wheel fell to the bottom of the tank	If in low sodium silicate conditions, it will mix with the sludge so that it interferes with the transfer process	2	3	6
8	Filter Tank	Filter not working	Dirty sediment filter	Failed to filter impurities in sodium silicate	speed up pump damage because there is much sludge	5	2	10

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No.	Item Description		Description of Failure		Effect of Failure	O	S	R
	Component	Functional Failure	Failure Mode	Failure Mechanism				
9	Production Pump	Unable to supply sodium silicate to tank	Pump stuck or beeping	Bearing worn/ damaged	Sodium silicate in the tank is not optimal and interferes with the production process	5	4	20
			Leak in seal	Broken pump seal	Sodium silicate drips and will pollute the environment	4	3	12
			Trip	Motor burn	The transfer process is disrupted, and the production line is not optimal	4	4	16
10	Evaporator	Failed to set the desired thickness	Heating coil performance drops	lack of care	Decreased production is detrimental to the company	2	2	4
11	Agitator	The agitator fails to spin	Motor stuck	lack of care	Inhibits production	4	3	12
12	Storage Tank	The tank cannot maintain the volume of sodium silicate stored in it	The tank wall has a leak	Chemical corrosion	Sodium silicate is released into the environment and causes pollution	3	4	12
			Leak in the utility hole	Closing the utility hole that is not tight enough		2	5	10
			Leakage of the connection pipe connected to the tank	Corrosion of the pipe-to-tank connection		3	4	12
13	Transfer Pipe	Cannot drain sodium silicate to the maximum	Leak in the pipe	Corrosive elbow joint	Sodium silicate is released into the environment and causes pollution	4	3	12

through routine inspections at least every two months so that the ball valve is maintained and its functions properly and the life of the Ball Valve can be longer.

b) It is very important to replace ball valve components that are considered old due to age of use to avoid malfunctions in the ball valve.

c) The ball valve used is still in manual form, so it is necessary to replace the valve equipment with a quick valve type operated by interlock.

CONCLUSION

This study has shown that the highest risk value is dissolver tank leaks, the production pump not working, and the ball valve stuck. This research proves that some hazards have not been evaluated and controlled, so there are still some failures in the production process of Sodium Silicate.

DISCLOSURE

Author Contribution

All authors have contributed to this research process, including conception and design, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article, and collection and assembly of data.

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Conflict of Interest

There is no conflict of interest in this manuscript.

Ethical Consideration

This research was approved by the Health Research *Ethics* Committee of the Department of Public Health, Nahdlatul Ulama University Surabaya. Letter of exemption Ref. No. 21.37/HPZH.21/ LL/2021

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