RISK MANAGEMENT OF ILC – SLC IN PT. SEMEN INDONESIA (Persero), Tbk. TUBAN PLANT III

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Abstract— In-Line-Calciner (ILC) and Separate-Line-Calciner (SLC) are the equipments of pre-calcinations process in mostly modern industrial cement kilns that have importance due to its impacts for fuel consumption, pollutant emission and final cement quality. Any failures in this system will lead to stop the clinker production process and increase losses of the company since 60% calcinations process has done outside the rotary kiln. Therefore risk management needs to be done in this system. In this paper, HAZOP method has been used to determine hazard identification and analysis with two nodes that are ILC and SLC with each has five parameters to measured and controlled that are Preheater Exit %O2, Preheater Exit %CO, Preheater Exit Gas Temperature, Stage IV Calciner Exit Material Temperature, and Preheater Exit Pressure Difference. Guide word and deviation determination based on control chart constructed from operational data of each components of measurement points. Likelihood estimation based on data operational failure that taken along 180 days while consequence estimated based criteria as well as the data posed by control chart. Risk criterion of measurement points in each node produced by multiplying likelihood and consequence. Based on the analysis known that any hazards or failures occur in the component of measurement points in each nodes have potential causing main risks as operational clinker production process has to stop and inappropriate product quality standard mainly because of incomplete preheating and combustion process. To reduce the risk in the system, routine preventive maintenance and calibration should be done especially in Preheater Exit Pressure Difference measurement point components that have an extreme level of risk and indicates any potential hazards that causing operation process to stop.

Keywords— ILC, SLC, Risk Management, HAZOP, hazards identification.

I. INTRODUCTION

Cement has an important role for construction fields. High rate of civil development nowadays has a big impact to increase production of the cement industries in Indonesia and the whole world. According to International Cement Review in 2012, Indonesia was in 8th position as cement consumer and 53rd position of cement production in the world [1]. One of the wellknown cement industry in Indonesia is PT. Semen Indonesia (Persero), Tbk. (PTSI) that has main production as various types of cement with 43,7% market share of Indonesia [2]. In the other hand, PTSI is the biggest cement manufacturer in Indonesia, one of its factory is located at Tuban East Java. This factory divided into four plants that is Tuban I, Tuban II, Tuban III, and Tuban IV with each production capacity about 2,9 million ton per year in 2014 [2]. Cement production process consists of following three basic processes that is raw material process, clinker burning process and finish grinding process [3]. In PTSI Tuban plant, processing stages start from Crusher unit, Raw Mill unit, Kiln unit, Finish Mill unit, and Packing unit. One of most important stage is happened in the Kiln unit which has function contacting the hot flue gases and raw meal materials and as a place of chemical reactions to build clinker. The Kiln unit consists of suspension preheater and calciner, rotary kiln and clinker cooler. Suspension preheater is an equipment that has function to preheat raw meals before entering rotary kiln. Most of modern suspension preheater integrated with calciner to precalcinate the heated raw meals. This calciner divide into two major types, In-Line Calciner (ILC) and Separate-Line Calciner (SLC). The advantages of using calciner are [4]-[5] : a). Reduce the dimension of the kiln and thermal load especially for the kilns with big capacity, b). Reduce energy demand and minimal calcination of the kiln that have impact to reduce considerably the exhaust gases and the kiln heat losses to the environment, c). Increase the capacity of production to twice in comparison to using simple preheater, d). The use of fuels with relatively low thermal capacity due to lower temperature required in the calciner, e). Reduce calcification percentage in the rotary kiln decrease its thermal load and improves its functional stability, f). Increase the lifetime of refractories in the rotary kiln since its functional stability. Calcination level of ILC – SLC outlet about 90 – 95%, and it consumes about 60% of the total fuel [5]-[6]. In the other hand, 60% of calcinations process has been done outside the rotary kiln which means the ILC –SLC should be controlled. Any failures that happened in this ILC – SLC equipments will increasing the risks of the Kiln unit system due to the important effects to fuel consumption, pollution emission and final quality of productions. Based on this facts, risk management steps have to be done to the equipments in order to identify possible hazards that can lead into potential risks. The main goal of this paper is to identify all possible hazards that can appear within the system using HAZOP (Hazard and Operability Analysis) method as a technique to identify hazards. Identifying

hazards, analysing and evaluating the risks are the first step towards successful risk management [7]. HAZOP is a qualitative method with a systematic and structured assessment of a planned or operation in order to define and identify hazards that can cause risks to human resources or equipments [8]. This technique using the help of guidewords which are applied on various system parameters [9].

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

Risk Assessment is the first step to prevent accidents within technical processes that divided into three main steps : risk identification, risk analysis and risk evaluation [14]. The data used in this paper are documents and pictures of the process in the ILC – SLC PTSI Tuban Plant III. These documents include process flow diagram (PFD), piping and instrumentation diagram (P&ID), time to failure of each component in ILC – SLC for 180 days and the data process of ILC – SLC components taken each hour for a month sampled from January, June, July and August 2015 up to 100 sample data. By using HAZOP method, steps to identify hazards are [7]-[8]:

1. Determine *nodes* based on the P&ID of the process where all parameters describing the system can be identified.
2. Determine *guideword* in each *nodes* using operational data processes of each component that presented by control charts to figured the deviations of the process.
3. Record the possible causes analysis of deviation and other related information in the HAZOP worksheet.

Nodes in this paper are divided into node 1 ILC and node 2 SLC as the system in the **Fig. 1** below.



Fig. 1. Boundary of the ILC – SLC system. Based on Central Control Room Tuban Plant III.

Estimation of the risk consists of likelihood and consequence analysis. Likelihood is frequency of the possibility of the risk can occur in a component at a some time period [10]. Likelihood is the result from comparison between the number of operational days (T) to the value of of MTTF (Mean Time To Failure). Likelihood is determined by Equation (1) :

$$Likelihood = \frac{T}{MTTF} \quad (1)$$

MTTF (Mean Time To Failure) at the failure rate (λ) obtained from failures data contained in the operational data with operational stops or fails in it.

$$MTTF = \frac{1}{\lambda} \quad (2)$$

Consequences was determined qualitatively based on impacts of the hazards that have been identified [11]. In addition, consequences can be estimated from based on a control chart constructed from the data on the process of each component [12]. Risk analysis is done by multiplying the calculated likelihood and consequences. The combination of risk is obtained by using a risk matrix as shown in **Table 1** [13].

Table 1 : Risk Matrix

	CONSEQUENCE				
LIKELIHOOD	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Almost Certain (5)	Medium	High	High	Extreme	Extreme
Likely (4)	Low	Medium	High	High	Extreme
Possible (3)	Low	Medium	Medium	High	High
Unlikely (2)	Low	Low	Medium	Medium	High
Rare (1)	Low	Low	Low	Low	Medium

III. RESULTS AND DISCUSSION

3.1. Hazards Identification of ILC – SLC system

Based on operational data processes recorded in the CCR Tuban III, basic measured parameters that determine the success of ILC – SLC process are O2 and CO gas analyser, material exit temperature, gas exit temperature, and pressure difference at the preheater exit. These parameters have each measurement points. Node 1 and node 2 divided into these measurement points as shown in the **Table 2.**

Table 2 : Node 1 and 2 Measurement Points

Measurement Point	Description
443AN1AT409	ILC Preheater Exit O2 Gas Analyser
443AN1AT410	ILC Preheater Exit CO Gas Analyser
443PH1PT473	ILC Preheater Exit Gas Temperature
443PH1PT433	ILC Calciner Stage IV Material Temperature
443FN1PT401	ILC Preheater Exit Pressure

Measurement Point	Description
443AN1AT449	SLC Preheater Exit O2 Gas Analyser
443AN1AT450	SLC Preheater Exit CO Gas Analyser
443PH1PT472	SLC Preheater Exit Gas Temperature
443PH1PT432A	SLC Calciner Stage IV Material Temperature
443FN2PT441	SLC Preheater Exit Pressure

Each node has measurement points transmitter which is then used to set the process. Process variable of each instrument displayed on the DCS screen and analyzed in a control chart to determine guideword and then consequences. As a sample, control chart of 443PH1PT433 (Material Exit Temperature ILC) shown in the **Fig. 2.**

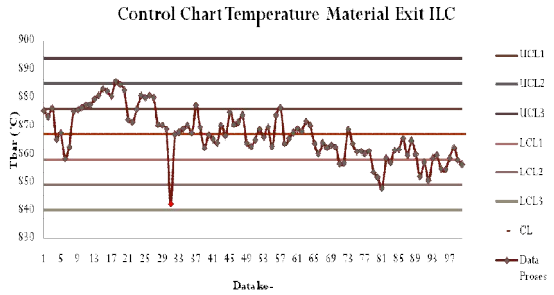


Fig. 2 : Control chart of 443PH1PT433 (Material Exit Temperature ILC)

From x-chart can be seen that more data operate above the center line value, that is mean the operating conditions of the system are often in high temperature conditions. Therefore, guideword of 443PH1PT433 (Material Exit Temperature ILC) is high which indicates that the deviation is at high temperature. Guideword determination for each measurement points in node 1 and 2 are shown in **Table 3.**

Table 3 : Guideword of node 1 and node 2

Measurement Point	Description	Guideword	Deviation
443AN1AT409	ILC Preheater Exit O2	More	More Flow
		Less	Less Flow
443AN1AT410	ILC Preheater Exit CO	More	More Flow
443PH1PT473	ILC Preheater Exit Gas Temperature	High	High Temperature
443PH1PT433	ILC Calciner Stage IV Material Temperature	High	High Temperature
443FN1PT401	ILC Preheater Exit Pressure	High	High Pressure
		Low	Low Pressure

Measurement Point	Description	Guideword	Deviation
443AN1AT449	SLC Preheater Exit O2	More	More Flow
		Less	Less Flow
443AN1AT450	SLC Preheater Exit CO	More	More Flow
443PH1PT472	SLC Preheater Exit Gas Temperature	High	High Temperature
443PH1PT432A	SLC Calciner Stage IV Material Temperature	High	High Temperature
		Low	Low Temperature
443FN2PT441	SLC Preheater Exit Pressure	High	High Pressure
		Low	Low Pressure

3.2. Estimation and Analysis of Risk

Risk estimation is done by combining likelihood and consequences. Estimation of consequences are based to the data that forms the boundary line UCL or LCL in the control chart. For example, for 443PH1PT433 in **Fig 2** the data has reached over the third lower control limit so the consequence is worth 4. Estimation of likelihood is built based on the data failures within 180 days. Likelihood criteria determined by using the ratio between operating time with MTTF in equation (1) and (2). Consequences and likelihood of each measurement points in node 1 and node 2 shown in **Table 4** and **Table 5.**

Table 4 : Criteria of consequences of node 1 and 2

Measurement Point	Description	Guideword	Deviation	Consequences
443AN1AT409	ILC Preheater Exit O2	More	More Flow	3
		Less	Less Flow	
443AN1AT410	ILC Preheater Exit CO	More	More Flow	5
443PH1PT473	ILC Preheater Exit Gas T	High	High Temperature	4
443PH1PT433	ILC Calciner Stage IV Material T	High	High Temperature	3
443FN1PT401	ILC Preheater Exit Pressure	High	High Pressure	4
		Low	Low Pressure	

Measurement Point	Description	Guideword	Deviation	Consequences
443AN1AT449	SLC Preheater Exit O2	More	More Flow	4
		Less	Less Flow	
443AN1AT450	SLC Preheater Exit CO	More	More Flow	5
443PH1PT472	SLC Preheater Exit Gas T	High	High Temperature	4
443PH1PT432A	SLC Calciner Stage IV Material T	High	High Temperature	3
		Low	Low Temperature	
443FN2PT441	SLC Preheater Exit Pressure	High	High Pressure	4
		Low	Low Pressure	

Table 5 : Criteria of Likelihood of node 1 and node 2

Measurement Point	Total Failures	Total Hours	MTTF	Likelihood	Likelihood Criterion
443AN1AT409	8	400	50	86.4	3
443AN1AT410	8	400	50	86.4	3
443PH1PT473	11	117.8	10.70909	403.395586	1
443PH1PT433	8	91.3	11.4125	378.532311	1
443FN1PT401	12	1176.8	98.06667	44.0516655	4
Measurement Point	Total Failures	Total Hours	MTTF	Likelihood	Likelihood Criterion
443AN1AT449	8	407	50.875	84.9140049	3
443AN1AT450	8	407	50.875	84.9140049	3
443PH1PT472	8	202.2	25.275	170.919881	2
443PH1PT432A	9	266.4	29.6	145.945946	2
443FN2PT441	12	1195.4	99.61667	43.3662372	4

By using risk matrix from the company as a guidance, risk of each measurement points of node 1 and node 2 results as shown in the **Table 6**.

Table 6 : Criteria of Risk Node 1 and 2

Node 1

Measurement Point	Description	Risk Criterion
443AN1AT409	ILC Preheater Exit O2	M
443AN1AT410	ILC Preheater Exit CO	H
443PH1PT473	ILC Preheater Exit Gas T	H
443PH1PT433	ILC Calciner Stage IV Material T	H
443FN1PT401	ILC Preheater Exit Pressure	E

Node 2

Measurement Point	Description	Risk Criterion
443AN1AT449	SLC Preheater Exit O2	M
443AN1AT450	SLC Preheater Exit CO	H
443PH1PT472	SLC Preheater Exit Gas T	H
443PH1PT432A	SLC Calciner Stage IV Material T	H
443FN2PT441	SLC Preheater Exit Pressure	E

Based on HAZOP worksheet analysis in **Table 7** and the risk estimation above**,** the result of risk criterion in node 1 and node 2 are equal that are Medium for %O2 Preheater Exit measurement point, High for %CO Preheater Exit, Gas Temperature Preheater Exit and Material Temperature Stage IV ILC/SLC measurement point, and Extreme for Pressure Difference Preheater Exit measurement point due to the frequency of failure occurence in this point is the highest among all. ILC – SLC system is a feeder system for pyroprocessing in the rotary kiln. Any deviations of the parameters will have impacts to operational process of ILC – SLC system as :

1. Leakages allow air to enter the process equipments which operate normally in vacuum condition causing *false air*. Increase of oxygen percentage in the %O2 Preheater Exit measurement point indicates *false air* occurs. The oxygen level needs to be controlled as important parameter to determine fuels and combustion air necessity to reach an ideal burning reaction. If air supply decreases, ideal combustion will not be reached causing CO level increase and the heat will decrease. Same condition happens if there is excess air supply, the excess air will cooling down the heat in the system. An incomplete and not ideal combustion will affect the products quality. O2 Preheater Exit percentage in PTSI Tuban Plant III is controlled around 3%.
2. Increase of CO level in %CO Preheater Exit indicates incomplete burning quality. Excess of CO level absorb heat in the system causing ideal calcinations temperature can not be reached. This leads clogging occurs in the cyclones that can be one of causes the clinker production process stops. CO Preheater Exit percentage in PTSI Tuban Plant III is controlled no to over 1%.
3. Exhaust gas flow with exceed hot temperature can damage the equipments and shorten its lifetime. Lower ends corrosion of pressure and temperature transmitters is one of general damages that occurs as result of continual contact with high temperature. Unstable gas temperature also affect the alkali-chlorine-sulphur in the system and forms coating that clog the cyclones. This motivates the clinker production to stop operate. Gas Temperature Preheater Exit in PTSI Tuban Plant III is controlled not to over 450˚C.
4. Exceed hot material temperature in calciner outlet changes the form of material into more adhesive and sticks to the bottom calciner which clog the calciner and make its operation stops. If lower limit of ideal material temperature is not reached or material temperature too 'cold' will affect the product quality. Material Temperature ILC/SLC Stage IV in PTSI Tuban Plant III is controlled about 830-870˚C for ILC and 840-890˚C for SLC.
5. A significant increase of pressure difference/drop indicates abnormal behavior of operational ILC – SLC process which can caused by cyclones blockage in the preheater or calciner and has impact to stop clinker production process. This blockage can caused by abnormal materials temperature. Low pressure difference causes gas and material separation process incomplete and affect the product quality. Preheater Exit Pressure value in PTSI Tuban Plant III is adjusted with ILC/SLC coal feed. This meant that pressure difference/drop value in at the preheater outlet depends on stable combustion condition.

Table 7 : HAZOP worksheet analysis

HAZOP Worksheet
Project Facility : ILC SLC Unit Kiln Tuban III PTSI
Section of Facility : Node 1 ILC
Section of Facility : Node 1 SLC

Component	Deviation	Consequences	Risk			Safe-Guards	Recommendations
			S	L	R		
443AN1AT409 (ILC Preheater Exit O2)	*More Flow*	Terjadi kebocoran/*false air* pada preheater menyebabkan peningkatan konsumsi bahan bakar dan menyerap panas dalam sistem	3	3	M	*Gas detector, automatic stop system, ILC O2 analyser unit alarm*	Perawatan dan pemeliharaan peralatan, pengaturan komposisi bahan bakar antara batu bara dan IDO
	Less Flow	Proses pembakaran tidak sempurna meningkatkan kadar CO					
443AN1AT410 (ILC Preheater Exit CO)	*More Flow*	Proses pembakaran tidak sempurna mempengaruhi kualitas *clinker*	4	3	H		Perawatan dan pemeliharaan peralatan, pengaturan komposisi bahan bakar antara batu bara dan IDO
443PH1PT426 (ILC Preheater Exit Gas T)	*High Temperature*	*Overtemperature* gas mempengaruhi masa pakai / *lifetime* peralatan	3	5	H	Safety, Protection, and Operational Interlock	Pemeliharaan rutin 3 kali dalam sebulan seluruh TT dan PT pada ILC
		Overtemperature gas menyebabkan *coating* yang dapat menyumbat ID Fan					
443PH1PT433 (ILC Calciner Stage IV Material T)	*High Temperature*	*Overtemperature* material berpotensi membentuk *clogging* pada kalsiner dan inlet kiln	3	5	H	Safety, Protection, and Operational Interlock	Pemeliharaan rutin 3 kali dalam sebulan seluruh TT dan PT pada ILC
		Bottom calciner atau inlet kiln tersumbat menyebabkan kiln berhenti beroperasi					
443PH1PDT400 (ILC Preheater Exit Pressure)	*High Pressure*	*Overpressure* mengindikasikan siklon preheater atau kalsiner tersumbat	4	5	E	Safety, Protection, and Operational Interlock	Pemeliharaan *immersion tube*
	Low Pressure	Pemisahan material dan gas tidak sempurna mempengaruhi kualitas *clinker*					Menjaga laju ILC coal feed
443AN1AT449 (SLC Preheater Exit O2)	*More Flow*	Terjadi kebocoran/*false air* pada preheater menyebabkan peningkatan konsumsi bahan bakar dan menyerap panas dalam sistem	3	3	M	*Gas detector, automatic stop system, ILC O2 analyser unit alarm*	Perawatan dan pemeliharaan peralatan, pengaturan komposisi bahan bakar antara batu bara dan IDO
	Less Flow	Proses pembakaran tidak sempurna meningkatkan kadar CO					
443AN1AT450 (SLC Preheater	*More Flow*	Proses pembakaran tidak sempurna mempengaruhi kualitas *clinker*	4	3	H	*Gas detector, automatic stop system, ILC CO*	Perawatan dan pemeliharaan peralatan, pengaturan
443PH1PT466 (SLC Preheater Exit Gas T)	*High Temperature*	*Overtemperature* gas mempengaruhi masa pakai / *lifetime* peralatan	3	5	H	Safety, Protection, and Operational Interlock	Pemeliharaan rutin 3 kali dalam sebulan seluruh TT dan PT pada SLC
		Overtemperature gas menyebabkan *coating* yang dapat menyumbat ID Fan					
443PH1PT473 (SLC Calciner Stage IV Material T)	*High Temperature*	*Overtemperature* material berpotensi membentuk *clogging* pada kalsiner dan inlet kiln	3	5	H	Safety, Protection, and Operational Interlock	Pemeliharaan rutin 3 kali dalam sebulan seluruh TT dan PT pada SLC
	Low Temperature	*Bottom calciner* atau inlet kiln tersumbat menyebabkan kiln berhenti beroperasi					
443PH1PDT440 (SLC Preheater Exit Pressure)	*High Pressure*	*Overpressure* mengindikasikan siklon preheater atau kalsiner tersumbat	4	5	E	Safety, Protection, and Operational Interlock	Menjaga laju SLC coal feed
	Low Pressure	Pemisahan material dan gas tidak sempurna mempengaruhi kualitas *clinker*					Pemeliharaan *immersion tube*

CONCLUSIONS

Risk estimation and analysis of measurement points at ILC – SLC system in PTSI Tuban Plant III was done and major conclusions are as follows:

1. The result of risk criterion in node 1 and node 2 are equal that are Medium for %O2 Preheater Exit measurement point, High for %CO Preheater Exit, Gas Temperature Preheater Exit and Material Temperature Stage IV ILC/SLC measurement point, and Extreme for Pressure Difference Preheater Exit measurement point due to the frequency of failure occurence in this point is the highest among all**,** the result of risk criterion in node 1 and node 2 are equal that are Medium for %O2 Preheater Exit measurement point, High for %CO Preheater Exit, Gas Temperature Preheater Exit and Material Temperature Stage IV ILC/SLC measurement point, and Extreme for Pressure Difference Preheater Exit measurement point due to the frequency of failure occurence in this point is the highest among all.
2. Any hazards or failures occur in the component of measurement points in each nodes have potential causing main risks as operational clinker production process has to stop and inappropriate product quality standard mainly because of incomplete preheating and combustion process. To reduce the risk in the system, routine preventive maintenance and calibration should be done especially in Preheater Exit Pressure Difference components that have an extreme level of risk and indicates any potential hazards that causing operation process to stop.

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