Process Safety Index in Chemical Process

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Abstract*— Safety is a strategy to reduce the risk of major process accidents. The principle of a safety is to reduce the risk of fails and can be applied easily as the inherent safety. the research which assesses the safety and appeared have a lot of new methods. This study tried to summarize some of the existing methods. The study focused on the case of making methyl methacrylate (MMA) with acetone cyanohydrin (ACH). The processing manufacturing production is divided into four stages or routes. Which are production of hydrogen cyanide (HCN), acetone cyanohydrin (ACH), HMPSA/HMPSE and methyl methacrylate (MMA). Safety assessment is a stages with standardization. Standardization aims to ease look at the risk level of a route. Assessment standardization it produces characteristic safety assessment of the risk level. The level of these characteristics assess any level of danger when the process conditions of a factory. Each production process of the plant there are several production steps. The steps in the production process including preparation, reaction, separation and purification. Of these processes often occur a failure. Then table the characteristics of this suggested to simplify petrified assess how the level of security in the process. In research took a case of making MMA with ACH. The process of making this MMA has four step process HCN, ACH, HMPSA / HMPSE and MMA. The four steps greatest potential failure or hazard is found in the first step with the characteristic 'Moderate', the according to the characteristics of the proposed table.

***Keywords*— Inherent Safety, Safety Assessment, Risk Level**

I. INTRODUCTION

The major accidents in the chemical industry such as the case of chemical plant explosion in Flixborough (UK) 1974 Bhopal gas leak in India in 1984, the explosion of LPG installations Mexico City in 1984 and the other [1]. Security is a strategy used to reduce the risk of major process accidents. The safety principles can be used to create a protection or are used to determine the level of danger a process. The accident risk reduction was applied using the inherent safety strategy (Inherent) to reduce the danger [2].

A process failure in an industry is caused by operator or equipment failure. Methods are used to determine the level failure of a production process [3]. To identify the level of danger is to reduce risk. The process identification and implement ware called inherent safety design in a particular context [4].

TABLE 1.
TOTAL INHERENT SAFETY INDEX [2]

Chemical Inherent Safety Index (I_{CI})		Process Inherent Safety Index(I_{PI})	
Heat of main reaction	I_{RM}	Inventory	I_I
Heat of side reaction	I_{RS}	Temperature	I_T
Chemical Interaction	I_{INT}	Pressure	I_P
Flammability	I_{FL}	Equipment	I_{EQ}
Explosiveness	I_{EX}	Process Structure	I_{ST}
Toxicity	I_{TOX}		
Corrosiveness	I_{COR}		

TABLE 2.
CHARACTERISTIC OF THE ASSESSMENT OF THE RISK LEVEL

Risk Level	Index		
Severe	0,751	-	1,00
Heavy	0,501	-	0,75
Moderate	0,251	-	0,50
Light	0	-	0,25

TABLE 3.
THE COMPARISON OF THE PREVIOUS RESEARCH

Route	Method		
	PIIS	ISI	NuDITS
Route 1	27	25	423,13
Route 2	16	21	382,12
Route 3	9	21	416,12
Route 4	12	19	403,47

TABLE 4.
THE COMPARISON OF RESEARCH METHOD OF PREVIOUS

Route	Method		
	PIIS	ISI	NuDITS
Route 1	0,422	0,291	0,260
Route 2	0,250	0,244	0,235
Route 3	0,141	0,244	0,256
Route 4	0,188	0,221	0,248

TABLE 5.
THE COMPARISON CHARACTERISTIC

Route	Method		
	PIIS	ISI	NuDITS
Route 1	Moderate	Moderate	Moderate
Route 2	Light	Light	Light
Route 3	Light	Light	Moderate
Route 4	Light	Light	Light

Safety is a strategy used to reduce the risk from accidents. Risk reduction accident at main process and applied to strategy inherent safety to reduce the danger [2] Inherent safety is concept, security approach focusing on reduce the risk which is conditions. The identification process and apply safety in a development plans a plant are called inherent safety design [5]. There was harm reduction in a process can be described in inherent safety compared with the process control passive, active and procedural [4].

A plant built safely will be equipped with equipment control. The many strategies have been introduced to reduce or minimize the consequences of the accident. Thus should be built a safe situation so that workers can reduce the rate of accidents and there must be the maintenance of the equipment to prevent the occurrence of equipment failure [3].

To identify the hazard is by means reduce the risk of harm .One way to identify the level of danger is to reduce risk. The process identify and implement ware called inherent safety design in a particular context. Inherent safety design is being important aspect of process safety [5]. Concepts of production processes can be assessed

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using safety index. The safety index is used to improve process safety. The principle of process safety is carried out with development production processes and stages of conceptual design [6]. Lots of methods used to assess a safety. Among methods used in this study is PIIS, ISI, i-safe and NuDITS.

Prototype Inherent Safety Index (PIIS) is the first published index for evaluating safety in the process. This index measures evaluation of production processes in the chemical industry. Parameter that is used has 8 parameters. Parameters of chemical safety are inventory, flammability, explosiveness and toxicity. While process safety are temperature, pressure and heat reaction [6].

The formula in show Eq. 1,

$$Chemical = T + P + Heat\ Reaction + Yeid \quad (1)$$

$$Process = F + E + TOX + I \quad (2)$$

Inherent Safety Index (ISI) is an assessment developed for larger scope of the process. This assessment uses 12 parameters to evaluate, and divided into two main parameters chemical and process parameters in accordance with Table 1. Inherent Safety Index calculation formula [2],

$$I_{ISI} = I_{CI} + I_{PI} \quad (3)$$

$$I_{CI} = (I_{RM} + I_{RS} + I_{INT} + I_{FL} + I_{EX} + I_{TOX} + I_{CORRS}) \quad (4)$$

$$I_{PI} = I_I + (I_T + I_P + I_{EQ} + I_{ST}) \quad (5)$$

I-Safe as a comparison index is the process by using sub-index taken from ISI and PIIS. In addition, using the NFPA to determine the value of the chemical reactivity. To calculate the index of i-safe by counting each such reaction *Overall Safety Index* (OSI), *Includes Individual Chemical Index* ICI, *Individual Reaction Index* (IRI) and *Total Reaction Index* (TRI). The difference between the explosion limits for the material. The difference with the ISI and PIIS, including reactivity as a measure of stability [8].

$$ICI = N_f + N_t + N_e + N_r \quad (6)$$

Flammability (N_f), *Toxicity* (N_t), *Explosiveness* (N_e) and *Reactivity rating* (N_r). Then *Overall Chemical Index* (OCI) for the main reaction is equal to the maximum IC for all the chemicals involved in the reaction. IRI is calculated as the sum of the index parameter temperature (T), pressure (Rp), results (Ry) and heat the reaction (Rh), together with the score PIIS process plus the heat of reaction.

$$OCI = \max(ICI) \quad (7)$$

$$IRI = R_P + R_t + R_Y + R_h \quad (8)$$

$$ORI = \max(IRI) \quad (9)$$

Hazardous Chemical Index (HCI) is a maximum of ICI of all chemicals in the process. Similarly, Hazardous Reaction Index (HRI) is a maximum of IRI from all the main reaction in the process.

$$HCI = \max(ICI) \quad (10)$$

$$HRI = \max(IRI) \quad (11)$$

$$OSI = \sum(OCI + ORI) \quad (12)$$

Overall Safety Index (OSI) is the sum of the ORI and the sum of the OCI for any major reaction in the process. OCI is the dangerous nature of these different chemicals have high levels of toxicity, flammability, reactivity, or explosive substances. To account for this situation is known Worst Chemical Index (WCI), which is the sum of the maximum value flammability, toxicity, reactivity, and explosiveness sub-indices of all materials involved in the reaction steps.

$$WCI = \max(N_f) + \max(N_t) + \max(N_e) + \max(N_r) \quad (13)$$

Worst Reaction Index (WRI) by summing the maximum value of the index parameters of temperature, pressure, and heat the reaction results.

$$WRI = \max(R_P) + \max(R_t) + \max(R_Y) + \max(R_h) \quad (14)$$

$$TCI = \sum \text{ICI} \quad (15)$$

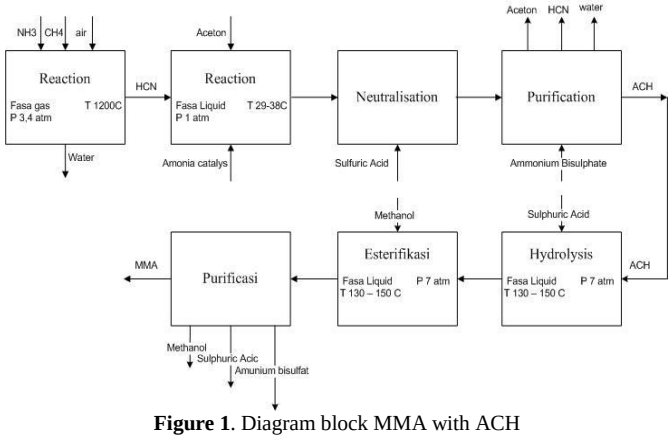

Figure 1. Diagram block MMA with ACH

For a process that involves just one main reaction, the values of IRI, HRI and WRI will be the same. Total Chemical Index (TCI) is a measure of the amount of harmful chemicals that are involved in these. It is a route with only one highly toxic chemical is safe compared to other routes with some highly toxic chemicals. It should be noted that the WCI and the TCI was calculated for all chemicals in the process. OSI along with three additional index that is used to determine these rink process as

follows. These was three additional index is subjective, we have weighted TCI, WRI, and WCI in that order [9].

NuDITS is the safety assessment. This new technique uses the numeric assessment method. Safety parameters that are used are temperature, pressure, heat reaction, yield, flammability, explosiveness, toxicity and inventory for the chemical industry. The assessment results can be used to easily identify the safest route between several alternatives of synthesis process and can determine the potential source of risk from the synthesis processes [3].

$$y = \frac{C}{1 + Ae^{-BX}} \quad (16)$$

$$B = \frac{4m}{C} \quad (17)$$

$$A = e^{Bk} \quad (18)$$

There are three main constants in the Eq. 6, 7 and 8. C is a indicated the maximum limit of the score where in the in the y value is always less than equal to C. in developing NuDITS, both the m and k value obtained from the data gathered from sources result previous method. m value is average value, k is slope, c is value 0 until 100. x and y are parameters.

II. METHOD

Every method has different way of safety assessment and index value. Therefor most level parameters assessed about the same value. To determine the risk level of any assessment, a standardization is needed. Table 2 is standardization table that will facilitate the assessment and give category of each step in the production processes.

Table 2 concerns the characteristics of the index assessment level where zero is the level of light hazard. While the index value approaching one is greater risk level. This risk level assessment can be used to estimate the area that has a great danger, and in case of failure the process can be prioritized in advance to mitigate them. Determine the characteristics of standardization in the table tied method is to use the data.

Standardization Assessment is an assessment of the total by using multiple sub-parameters. Standardization is done by using data based on statistical equations tied. Tied this data to integrate the data obtained can be known judging is correct or not.

The assessment level of safety using quantitative. This assessment will make it easy to determine the level of security by quickly and for taking precautions. Assessment using this ranking is the most frequently used assessment. How to vote by assuming the rank of each parameter. Where the value of the lowest ratings given by order of 1 and so further [8]. Because the result of this standardization will be characteristic of the various methods PIIS, ISI, i-safe and NuDITS.

The assessment integration are the judgments in total with equation 1 that combines with all aspects parameter. Tied this data to integrate data obtained for the judgment of has been true or not. Because the results from compared with the results of data from the previous method.

$$Integrasi = \frac{Score\ Parameter}{Total\ Score} \quad (7)$$

Analysis to determine the safety level of danger in a production process proposed in table 2. The table is to assess the level of danger when the process conditions of a factory. Each production process of the plant there are several production steps. The steps in the production process including preparation, reaction, separation and purification. Table 2 for ease of determining the level of the potential occurrence of a failure.

III. RESULTS AND DISCUSSION

The assessment in the study is carried out by various methods that have been done by previous researchers. Focus research is production of Methyl Methacrylate (MMA) with Acetone Cyanohydrin (ACH) process Fig 1.

Assessment aims to see how much the risk if accident occurs. Table 3 the processing manufacturing production is divided into four stages or routes. Which are production of HCN, ACH, HMPSA/HMPSE and MMA.

Analysis to determine the safety level of risk in a production process is proposed in Table 2. The assessment is standardization. Table 3 show the result of an assessment based on the previous method to be standardized. Standardization this value to ease the determination of a route aims characteristics. The assessment every a method of is having scope the same value. If the value of method that was too far could so method assessment there are several mistakes.

The comparison is taken with the same parameters. The results of standardization are in show Table 3 and Table 4. To find out the characteristics of risk level in Table 5 every steps of a production in the industry.

IV. CONCLUSION

The Assessment with standardization should ease in determining characteristic of the risk level. The Assessment show the most dangerous step is first step, with characteristics of 'Moderate'. While less dangerous step is the fourth step with characteristic of 'Light'. The three previous methods studied the same results. However, the method PIIS have a differing much compared with the ISI, i-safe and NuDITS. It is caused by different parameters. Assessment with standardization can be used also to analyze is it true of a methods.

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