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Accident Contributor Interconnection Study as a Basis for Accident Mechanism Prediction

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The accident rate in the chemical process industry (CPI) is not decreasing although the large majority of accident causes are known, foreseeable and could be prevented by existing knowledge. Continuous learning and improvement on experience feedback system is essential for process safety. In this paper, the experience feedback system is used to generate accident knowledge and understanding on accident mechanism. Accident data such as accident contributors are analysed and their interconnection matrix is develop. The matrix reveals three main functional groups of contributor to accident. Therefore, the likelihood of chronological event of accident could be predicted.

1. Introduction

Loss prevention in the chemical process industry (CPI) nowadays is very challenging due to rapid growth and changes in the industry (Prem et.al, 2010; Kidam et.al, 2012). To meet the demand, CPI are require to produce new chemicals at increase plant capacity with severe processing conditions. These directly increase the risk to life, property, environment, and business loss in case of an accident. Further, to remain comparative, the CPI makes several changes that indirectly affected the safety performance at workplace as listed by Kidam et.al. (2012). One of the changes is related to cost-cutting exercise that caused 'brain-drain' and 'corporate-forgetory' within organization. These seriously limit the ability of organization to learning from past experience. In general, the rapid growth and changes in the industry, makes chemical plant operation is more risky than before. As a result, accident rate in the CPI is not decreasing where similar accidents keep on happening from time to time. In this paper, learning from accident is enhanced by analyzing past major accident cases to create a new approach in accident prediction.

2. Accident Prediction

The influence of factors that contribute to accident occurrences can be explained by accident prediction model. According to TARC (2009), multivariate analysis is widely used to predict accident especially in road accident cases. There was also some accident prediction of road accident that uses Bayesian analysis such as the crash prediction model developed by Huang et. al (2008) using Bayesian analysis. Heydari and Amador-Jimenez (2012) also applying the Bayesian analysis framework to predict road accidents and identification of potential hazardous sites. Bayesian analysis has also been used as modelling tools in occupational accident prediction and statistic such as the one studied by Marcoulaki et. al (2012).

However, there are limited accident prediction model that has been used to predict accident in CPI. A study by Meel et.al (2007) use Bayesian theory to forecast incident frequencies, the causes, equipment involved and consequences by using the accident database in various chemical and petrochemical companies. Meel and Seider (2006) also used Bayesian analysis to predict and estimate the failure probabilities of safety systems and end-states in CPI and to accurately assess the probabilities of various

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accident scenarios and prediction of number of abnormal events that will occur in the next time interval based on the information from previous intervals. However, these accident prediction method used are mainly result in frequencies orientation, with limited visualisations of the interaction of the accident causes that lead to the accidents, despite the available historical data of the accidents.

Hence in this paper, the interaction between the accidents contributors is to be predicted with previous accident cases as bases. An in-depth analysis has been carried out to foresee the relationship between contributors of the accident through simple interconnection matrix.

3. Research Approach

For this research, the information on accident causes from Japanese Failure Knowledge Database (FKD) were analyzed which involve 364 cases of CPI-related accidents. Firstly, the accident contributor to the accident was identified. Since large majority of accidents are caused by more than one contributor, the main contributor and sub-contributor could be recognised. By definition, the main contributor was considered to be the main factor that immediately initiated or triggered the accident, while the sub-contributors also make a significant contribution to the accident; however, their roles are less important and are considered only as supporting factors. If the main contributor were removed, the accident would not happen at all or would occur with a much lower probability. Based on that the second step is to identified the main and sub contributor of accident cases. Next, the relationship between main and sub contributor are analyzed by using simple interconnection matrix. Their level of interaction are identified and classified into three indicators which is weak, moderate and strong. Finally, the functional groups of contributor to accident are generated where the likelihood of chronological event of accident could be predicted.

4. Accident Contributors

The accident cases in the FKD database were analyzed to find both the main and sub contributors to accidents. Based on the accident report in the FKD database, accident contributor is classified into 15 common categories as listed in Figure 1. Due to the multiple causes of accidents, there were 806 accident contributors are recognized from 364 accident cases. On average, there were 2.2 contributors per accident.

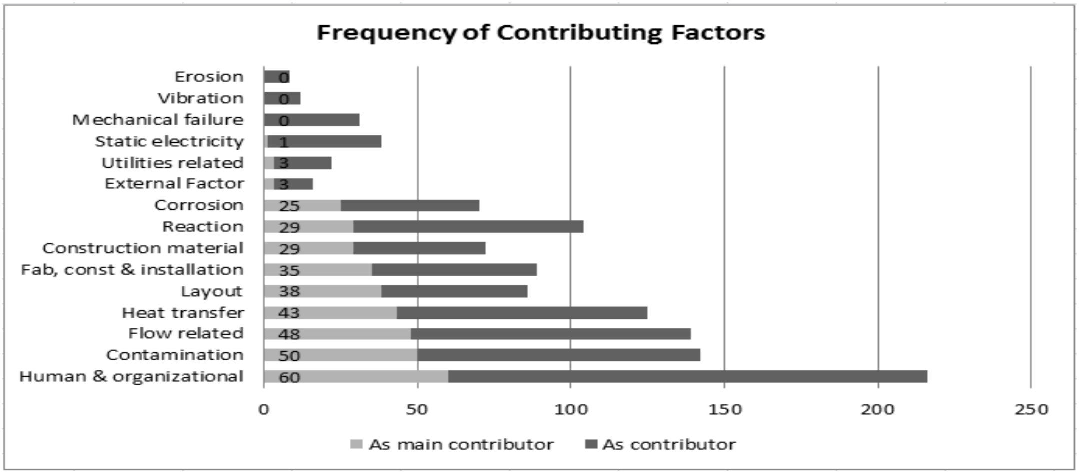

Figure 1: Frequency of contributing factor

Figure 1 shows the contributor that has been divided into their role as main contributor as well as sub contributor to the accident. It represents the frequency of each contributing factors as main and sub contributor. Figure 1 indicates that human & organizational factor has the largest frequency as contributor to the accident, however only 60 are identified as main contributor. Other common main contributor of accident are process contamination, flow related, heat transfer, layout and fabrication, construction and installation

5. Interconnection Study

Since the sub-contributor can be the supporting causes that triggered accident, therefore the contributors are related to one another. Significantly, the interconnection matrix of sub-contributors and main contributors has been carried out by Kidam et. al, (2012) to show the interconnection of all contributors as in Table 1. The numbers represent the accident frequency of the respective contributors.

Table 1: Number of interconnections between main and sub-contributors of accidents

Main contributors		Sub-contributors														
Human/organizationa	60		7	**12**	**11**	1	1	5	0	0	2	1	**10**	2	0	0
Contamination	50	**15**		4	2	3	0	**18**	2	3	1	1	6	3	1	0
Flow-related	48	**19**	**11**		4	2	1	5	1	2	1	1	2	3	0	1
Heat transfer	43	**16**	4	2		0	6	**10**	1	0	5	0	4	0	0	0
Layout	38	**17**	**9**	**8**	2		1	3	1	3	0	0	3	1	1	2
Fab. const. & inst.	35	5	0	2	**6**	2		1	3	2	1	2	2	**9**	5	1
Reaction	29	**9**	2	4	**10**	0	1		0	1	4	0	0	0	0	0
Const. material	29	**10**	1	**9**	1	1	6	2		**8**	0	1	**8**	1	1	1
Corrosion	25	4	**8**	2	2	1	2	1	6		1	4	0	**12**	1	3
Utilities	3	0	0	0	1	0	1	1	0	1		0	1	0	0	0
External factor	3	0	0	0	0	0	0	0	0	0	1		0	0	3	0
Static electricity	1	1	0	0	0	0	0	0	0	0	0	0		0	0	0
All contributors	364	156	92	91	82	48	54	75	43	45	19	13	37	31	12	8
Sub-contributors		96	42	43	39	10	19	46	14	20	16	10	36	31	12	8

From Table 1, it can be realized that there are either one way connection or two-way connection between the sub-contributors and main contributors. Hence, by referring to the Table 1, the interconnection between the main contributor and sub-contributor can be classified into three categories, namely strong (8-20 connections), moderate (4-7 connections) and weak (1-3 connections). The bold number of frequency represents a strong relation between the main contributor and sub-contributor. For instance, for human and organizational factors, it related strongly to flow-related, heat transfer and static electricity in triggering the accident. While the main accident contributor from failure of material construction is strongly related human and organizational factors and moderately connected to material corrosion and flow-related factors as sub contributor to the accident. Therefore, the interconnection matrix can further be translated into Figure 2 illustration where it visualizes the complicated interconnections of overall accident contributors.

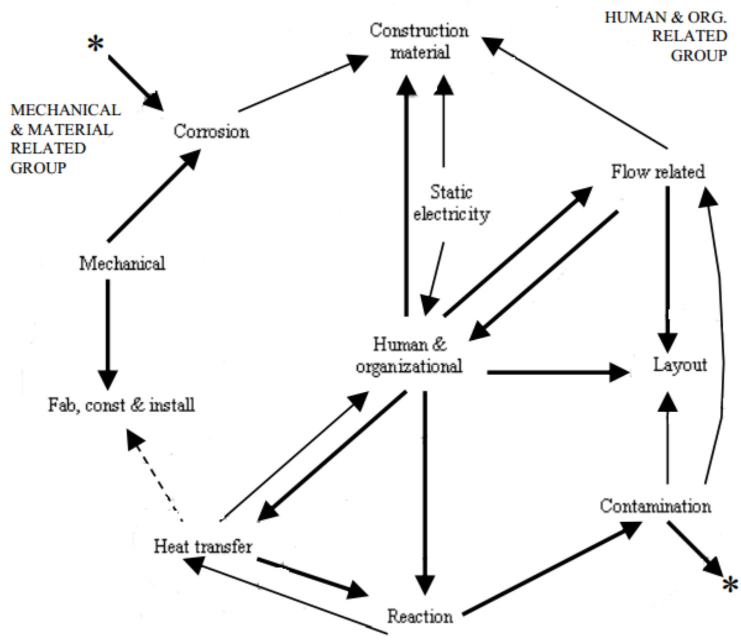

Figure 2: Interconnection of accident contributors.

Figure 2 indicates that the flow-related and heat transfer contributors are very much related to the human and organizational factors as it have strong relation in both way. Apart from that, the layout and construction material only connected to human and organizational in one way with a strong relation as well. Besides that, process contamination is also strongly linked with unwanted chemical reaction while heat transfer is very much linked to uncontrolled reaction in both ways. As under mechanical contributors, the mechanical failure connected strongly to construction material, corrosion and fabrication-construction-installation failure.

6. Functional Group of Accident Contributor

According to Figure 2, in general, the interconnection of accident contributors can be grouped into three main functional groups. The first is *human and organizational failure* where this group is specifically related to flow oriented problems (such as transfer and handling of chemicals), heat transfer activities, layout issues, static electricity control and construction materials. Second is *reaction, heat transfer and contamination* oriented group. Process contamination is created or caused by unwanted chemical reactions, which could be prevented by identifying possible routes and sources of the contaminants (i.e. layout and flow related factors) and by reducing operating errors (i.e. the human aspects). Heat transfer and reaction are very closely related and their effects on the process safety should be considered mutually. The third is the *mechanical & material* contributors group. Mechanical faults are affected by fabrication/construction/installation and by corrosion which are affected by construction materials.

Figure 3 can be explained in such a way that for first functional group, the human and organizational (H&O) aspect, H&O connected strongly with heat transfers failure while heat transfer failure related moderately to H&O. Heat transfer failure may be from sub-standard operation i.e. wrong setting at control panel which is also considered as human error, add up to the effect of heat transfer failure that lead to the accident. In the other hand, H&O also related strongly in both ways to flow related factors. Failure in flow related such as leakage and back flow may be due to poor finishing work related to maintenance and repair work of flow equipment such as valve, pipe and pumps. Hence, it can be connected to H&O through lack of supervision and contractor control management. H&O and flow related factors also strongly related to layout factor which considered as design error i.e. poor arrangement of process equipment and its piping connection. H&O also have a strong relation with unwanted or uncontrolled chemical reaction and construction material factor due to overlook on chemical reactivity or their incompatibility and inappropriate material selection for the process at the early stage of process plant design.

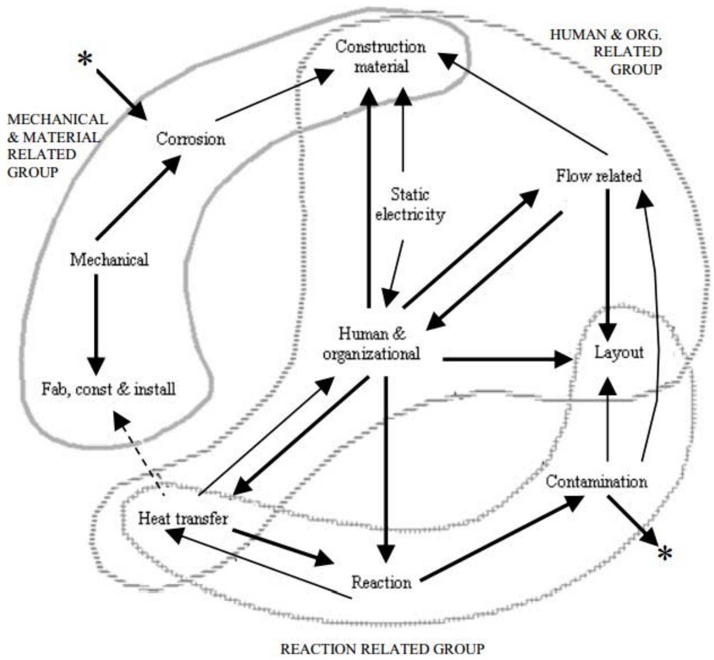

Figure 3: Interconnection between accident contributors with functional groups (the thicker the line the stronger the interconnection). The arrows show the direction from sub to main contributor.

In terms reaction failure (RF) group, reaction factor related in more than one way with heat transfer related failure. Failure in heat transfer function will affect the process condition in process equipment. In heating aspect, this is inevitably related to unwanted chemical reaction and runaway reaction. Vice versa in cooling aspect, uncontrollable chemical reaction is due to heat transfer failure. RF also shows a strong connection to contamination which is may due to by-product formation, impurities and recycles accumulation. Hence, with addition of RF, the process contamination will be increase the likelihood of unwanted chemical reaction. In addition, the unwanted chemical reaction might create or generate a hazardous compounds i.e. peroxide, that can cause fire and explosion.

For mechanical failure (MF) aspect, the MF is strongly related to poor fabrication/construction/ installation implementation. This may be due to poor finishing work and wrong installation of respective process equipment. MF also related strongly to corrosion in the process, while corrosion related moderately with inappropriate material construction.

7. Conclusions

Accident data is very powerful information to improve process safety. It can be exploited to generate a new knowledge that increases our understanding on accident prevention. In this paper, the experience feedback system is utilized to foresee the interconnection between accident contributors. It was found out that there is significant interconnection between accident contributors during accident process. Based on interconnection matrix, the interconnection level between main and sub contributors are identified and ranked accordingly to their frequency. Their direction on cause-effect also identified. At the end, the analysis reveals the three main functional group of accident connection which is human and organizational group; reaction, heat transfer and contamination group; and mechanical and material group.

In conclusion, the result of accident analysis on accident contributor interconnection enhanced our knowledge and understanding on how accident being raise in the CPI and provides idea on prevention strategy. Further work on the interconnection study is to develop the accident mechanism prediction model based on the interconnection level, direction and their functional groups.

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