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HAZARD ANALYSIS USING MULTI-COMPONENT ANALYSIS IN CHEMICAL PROCESSES

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Introduction

Chemical industries are composed of many complex processes having many recycle streams of energy and materials, regulated by environmental and safety considerations. As concern about protection from accidents and environmental problems increases, we need better process technology and safety management systems that can deal with process safety more efficiently in real time. Worldwide chemical processes are in need of off-site risk assessment as well as the on-site one. Korea is also preparing for executing Integrated Risk Management System along with PSM (Process Safety Management) and SMS (Safety Management System). However, there have been no systematic approaches and the criteria for generating virtual accident scenario, and it is impossible to get the unified or coherent assessment result. Accident scenario selection is essential for off-site consequence analysis, and analysis results may vary according to the selection of scenario. These kinds of analysis can be helpful in determining safety device, size of safety facility, and minimum distance from residential area. Therefore, more and more petroleum and oil companies are adopting these technologies to improve safety and productivity.

Problem in the establishment of accident scenarios

The most important part in a consequence analysis program is to determine an accident scenario, which is able to occur in a process. Generally, there are 3 kinds of methods in deciding accident scenarios; qualitative methods, quantitative methods, and methods using past accident data. HAZOP study and What-If analysis are examples of qualitative methods. Event Tree Analysis (ETA) is an example for quantitative method. Another method is to use past accident data; accident data for 5 years in the similar process are analyzed and used as an imaginary scenario. Each method has its own fortes and drawbacks, and its difficult to apply these methods in real consequence analysis. Its mainly because there is no selection criteria for the scenarios among the above methodologies. In qualitative methods, only kinds of accident results are presented and they cannot be applied in ranking or selecting accident scenarios. In qualitative methods, only kinds of accident results are presented and they cannot be applied in ranking or selecting accident scenarios. In quantitative methods like ETA, results change according to the selection of the initial event. In case of RM (Risk Management) Program of EPA, WCS (Worst Case Scenario) is calculated only using the maximum capacity and the result tends to be overestimated than the real one. Existing methods for calculating the risk depend heavily on the individual analysts view in generating accident scenarios; the calculation represents so variety of results. Sometimes, heavier risk in process is overlooked, because it would not consider the status of the process. Therefore, to overcome these drawbacks, a method based on the qualitative result, which considers process condition, material property, equipment behavior, etc., and able to apply the result in a quantitative manner is required.

Reasoning algorithm for accident scenario selection

In this study, we propose a new reasoning algorithm through process partition and process component analysis to improve the reliability of accident scenario selection. Process elements are analyzed and then the proposed strategy selects and generates the robust accident scenario of a worst case that is most likely to happen and should be foremost considered. The scenario reasoning scheme consists of three types of knowledge base and three reasoning algorithms: knowledge base (KB) of equipment property KB, material property KB, and process unit KB, and four algorithms of macro decompsition algorithme, quipment screening algorithm, equipment behavior analysis algorithm, and accident reasoning algorithm.

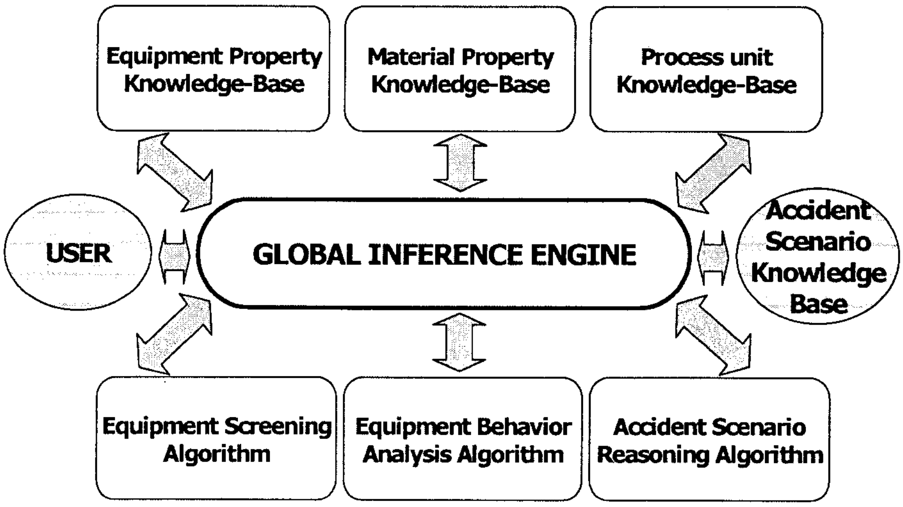

Fig. 1. Structure of Proposed system

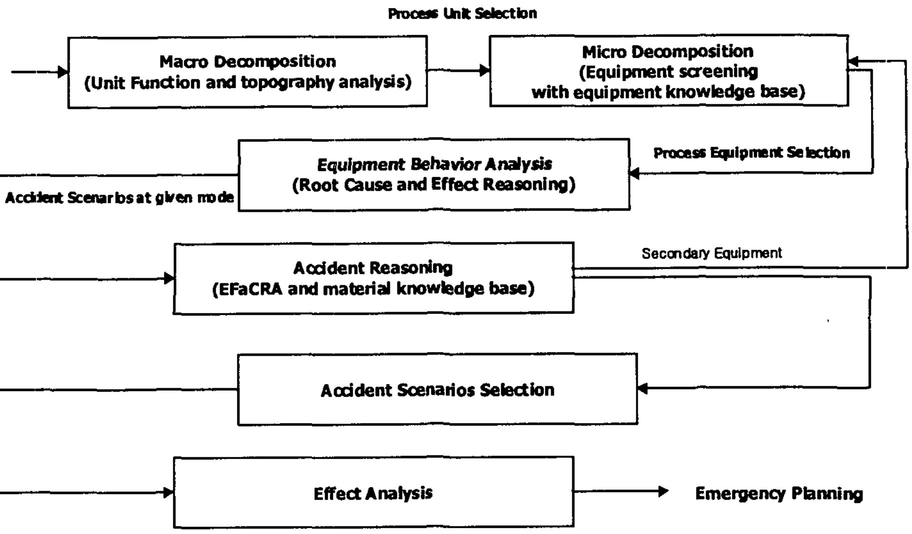

Fig. 2. Inference step of proposed system

Equipment property knowledge base is composed of equipment property such as handling materials, operating condition, flow rate, safety device, age, etc.. Material property knowledge base uses NFPA rating to describes toxicity, reactivity and flammability of handling materials. Process unit knowledge base consists of topography and meteorological characteristics, and accident scenarios are inferred according to the following steps: macro decomposition, micro decomposition using equipment screening algorithm, equipment behavior analysis, accident reasoning, and the effect analysis.

In the macro decomposition, process units are selected according to their functions and the meteorological condition around the area. For the decomposition, the chemical plant is classified into the feed system, reaction system, separation system, storage system, and utility system. Meteorological characteristics and the surrounding condition are also considered: the main unit is defined, and meteorological characteristics and the topography of the selected unit are considered. In the second step, we propose ESA (Equipment Screening Algorithm) analyzing the process condition and selecting the process equipment with higher priority risk ranking. Equipment characteristics such as material property, operating condition, flow-rate, capacity, safety devices, age, failure rate, accident history and repaired history are analyzed using ESA, which is a sequential reasoning method. In case of material property, we use NFPA (National Fire Protection Association) code to confirm the flammability and toxicity; the criterion of this property is more than 3 NFPA rating. In the next stage, we consider whether equipments with high flow-rate or capacity and the equipment is operated in high pressure or temperature, are determined. In the fourth stage, we decide whether the selected equipments have safety devices. In the final stage, we consider the age and accident history for individual equipment using the sequential screening method. The analyzed process elements are ranked and risk grades are determined. According to the grades, risk assessment

Table 1. Example of failure modes for equipment behavior

Equipment	*Valve*	*Pump*	*Heat exchanger*
Failure mode	Open Close Rupture Leak	Fail on Transfer off Seal leak/rupture Pump casing leak/rupture	Leak/rupture (tube to shell) Leak/rupture (shell to tube) Plugged Fouling

is performed.

In the equipment analysis using equipment behavior algorithm, the effect estimation for the selected equipment in the equipment screening algorithm is accomplished: equipment with high severity is researched to find a detailed accident scenario. We use effect analysis method for the failure mode of the selected equipment to identify single equipment failure modes and each failure modes potential effect on the system and the plant. This mode describes how equipment fails and is determined by the systems response and cause to the equipment failure. In the scenario selection, we infer possible effects and root cause depending on the failure mode of the equipment. Possible scenarios for each failure mode are so variable that risk rankings are assigned according to the potential hazard of material and the magnitude of abnormal situation.

In the accident reasoning algorithm, we infer the possible accident due to equipment behavior and material property. For example if the ultimate effect is valve breakage, then we can infer the possible accident is fire or explosion when material has a flammable property

(1)Valve leakage + Toxic materials(Nh ¡μ2) ¢¡ Personnel Injury

(2)No inlet flow + pump ¢¡ pump damage & malfunction

(3)Downstream equipment breakage + flammable materials(Nf>3) ¢¡ Fire or Explosion

Conclusion

A strategy for producing accident scenarios in quantitative manner, which is performed in the process design or operation steps, is proposed and tested to the flammable liquid storage facility. The result of the analysis enhances the reliability of the generated risk scenario and prevents the risks from being overestimated, so the result should be helpful in the proper process design and emergency planning. The strategy proposed here may be developed as a part of the quantitative process hazard analysis system, and be applied to the off-site consequence analysis.

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