17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)

Functional Modeling for Risk Analysis

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Abstract

This paper presents the use of functional modeling for risk analysis. Many methods exist to perform hazard analysis but they are not based on (explicit) models of the plant. The use of a model can help in having a semiautomatic and consistent way to perform the analysis. Besides the model can be, with little effort, reused in similar processes. A functional modeling methodolody is applied to a real process to prove the suitability of these techniques to perform risk analysis.

Keywords: functional modelling, risk analysis

1. Introduction

Process safety, accidents and environmental issues are increasing in importance in the process industry, and more due to public concerns and tighter regulations. Chemical and petrochemical plants and refineries are very complex processes that pose great challenges for the evaluation and the analysis of the hazards in them. Process plants are quite often operated at extreme pressure and temperature conditions in order to achieve a performance close to the optimum. This makes them more sensible and vulnerable to equipment failures.[1]
Today every plant has to perform a hazard analysis of the process. This means to make a systematic way an identification, evaluation and mitigation of the potential risks of the process that can lead to safety and health dangers, and cause considerable economic losses.There are a lot of methods to perform the hazard analysis, methods such as: Checklists, What-If Analysis, Failure Modes

and Effects Analysis (FMEA), Fault Tree Analysis (FTA) , Hazard and Operability (HAZOP) Analysis, etc.[2,3]

It seems reasonable, due to the hazard analysis importance and to the great time it takes to perform these analysis, that there is a lot of interest in developing intelligent (automatic) systems. These systems should perform the analysis in an exhaustive, detailed and consistent way.

It is in this framework where functional modeling can be a useful methodology to perform an automatic (or semi at least) analysis of the hazards of the process [4,5]. Functional modeling decompose the system according to the functionality of its components. These functionalities are hierarchically grouped in subgoals and goals.

Second section introduces functional modelling and shows the basics of the MFM methodology. Section three shows the model of a chemical plant (including control) using this technology and an analysis of “what happens if “. Finally section four draws some conclusions.

2. Multilevel Flow Modeling

Multilevel Flow Models (MFM) [6] are graphical models of goals and functions of technical processes [7]. The goals describe the purposes of a system and its subsystems, and the functions describe the system’s abilities in terms of flows of mass, energy, and information. MFM also describes the relations between the

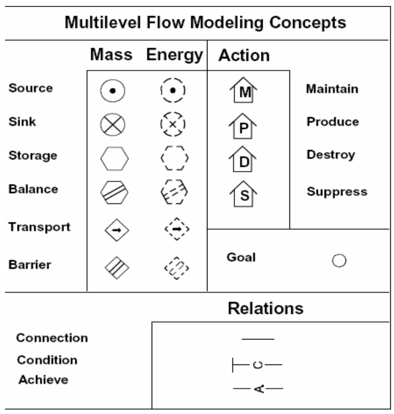

Fig.1. Multilevel flow modeling concepts

goals and the functions that achieve those goals, and between functions and the subgoals which provide conditions for these functions. Mass and energy flow structures are used to model the functions of the plant and activity and information flow structures are used to model the functions of the operator and the control systems.

These flow function concepts and their associated symbols are shown in Fig. 1. Using these concepts it is possible to represent knowledge of complex process plants. Besides the concepts shown there is another to model control structures, it is represented by the –AC-- (achieve by control) connection.

3. Chemical plant model

3.1. Plant description

The process to model and analyse is the production of monomethylamine nitrate (MMAN). The MMAN is an explosive produced through nitric acid and monomethylamine (MMA) gas. The reaction occurs in strirred tank reactor. The reaction is exothermic and it has to be kept under 60ºC, this is achieved circulating water through the jacket. The MMA is stored as liquified gas, so it needs to be vaporised before entering the reactor. The reaction product has to be kept above 55ºC in order to avoid crystallizations and under 70ºC to avoid produt decomposition. Both reactans have to be fed in stochiometric

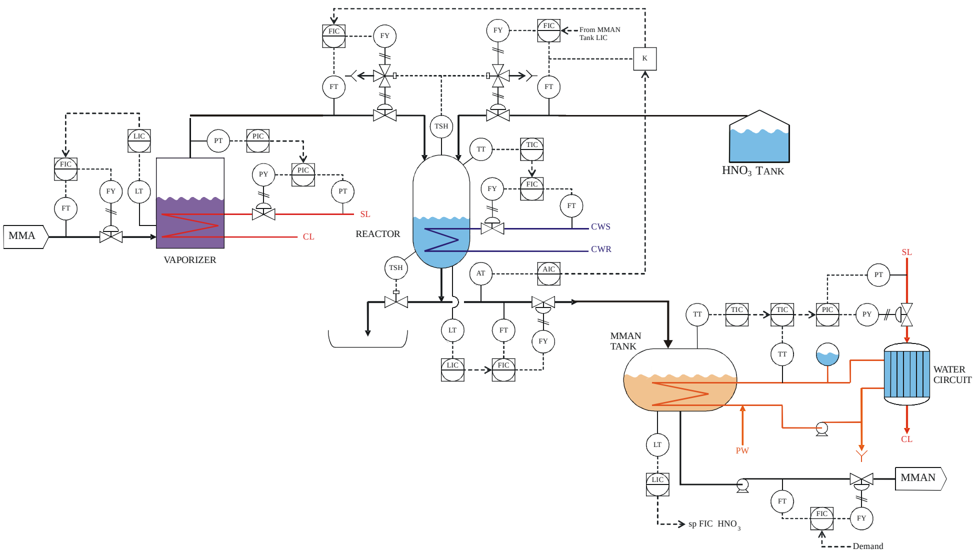

Fig. 2. MMAN process with control

proportions. Fig. 2. shows the described process including the control structures.

Control criteria is to guarantee safety, stability and quality. The criteria are:

- Safety: Stop feed when reactor reaches 65ºC to avoid runaway, discharge reactor content if temperature reaches 70ºC and control all the pressures.
- Stability: Production is set on demand, fresh feed and purge have to be considered in the water circuit and the mass balances have to be guaranteed.
- Qualitiy: Product quality is fixed by the stochiometry of the reaction and some inference of the product quality is needed.

3.2. Goals and subgoals

A set of goals and subgoals have been identified in order to guarantee a good plant behavior considered the aforementioned control criteria. These goals are:

- G0: Production of MMAN
- G1: Keep pressure in the vaporizer
- G2: Keep level in the vaporizer
- G3: Keep level in the reactor
- G4: Keep temperature in the reactor
- G5: Keep temperature in the storage tank
- G6: Keep level in the storage tank
- G7: Ensure product quality

All the goals have subgoals related with the stability of the control loops placed to achieve those goals. These control loops are shown in the previous Fig.2.

3.3. Flow and Energy structures

There are six structures, five corresponding to mass flows and one regarding to the energy flow. The reactants and product structure is described as an example: There are two paths, one is the nitric acid feed (So101) and the other one is the MMA feed (So102), this one goes to the vaporizer (St103) before entering the reactor (B101). Around the reactor a mass balance is applied and after it there is one path going to the storage tank (St104) and another one that is a barrier, in case the reactor content has to be discharged (Si102)
Similar structures exist for the other mass flows and for the energy flow. The complete functional model of the plant is presented in Fig.3.

3.4. Failure analysis

Following are some examples of different types of failures:
*Failure in the control loop that controls the nitric acid feed, subgoal 6.2.*Iºf this loop fails the outer loops related to it fail as well, these are subgoals 6.1 and 7.1

and 7.2 . These failure means that the goals 6 and 7 which are level in the storage tank and product quality cannot be achieved.

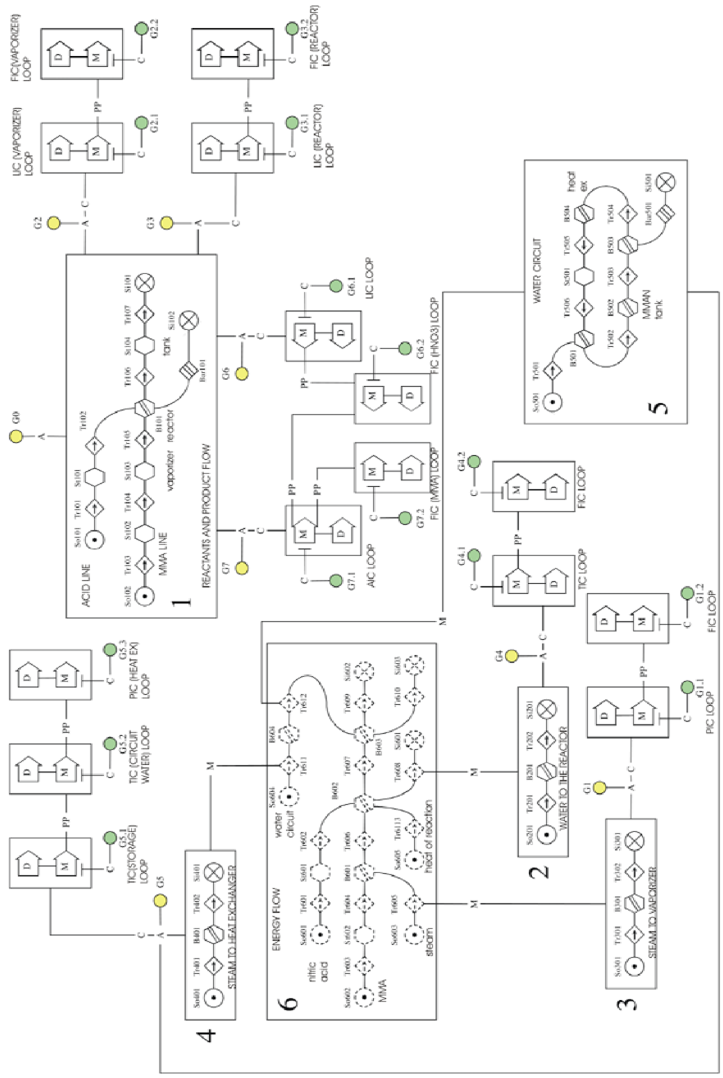

Fig.3. Functional model of the MMAN plant

Failure in a function. There is no steam available for the heat exchanger. Function So401. If this happens then goal 5 (keep temperature in the storage) is not achieved. If this means that the MMAN can become solid then it would condition the storage function (St104) and this structure would fail as well and all the objectives 0,2,3,6 and 7 would not be achieved. If this failure does not condition the storage function, then only the goal number 5 is affected.

If a goal is not achieved. If we detect that goal number 1 is not achieved, then we have that the pressure in the vaporizer is not what should be. The cause can be that the control loops are failing or that the structure number 3, steam to the vaporizer is failing. The cause can be problems in the steam line, pressure drops,etc. but it could be the heat transmission (Tr605) that fails due to incrustations.

4. Conclusions

In this paper the use of functional modeling for risk analysis has been presented. The MFM methodology has been applied to a real process including the control. Different types of failures and the following analysis have been presented. Although this technique (and similar ones as Goal Tree Success Tree) seems to be suitable for the analysis, some variations and extensions should be made in order to cope with a complete and thorough analysis. The benefit of using these techniques is the strength of using models allowing reusability and (combined with structural models) several hierarchical levels of analysis and its adaptability to be used for different heterogeneous applications.

Acknowledgements

This project has been sponsored by the Repsol-YPF foundation.

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