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A novel failure mode analysis model for gathering system based on Multilevel Flow Modeling and HAZOP

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ABSTRACT

In complex industrial system, such as gathering system, the high complex failure coupling relation among separate production process sections, personnel operation and equipment leads to a high complex potential hazard, which induces huge economic losses, environmental contamination, or human injuries. In order to insure system intrinsic safety and simplify failure mode analysis, this study proposes a novel failure mode analysis model (NFMA).

NFMA is developed based on Multilevel Flow Modeling (MFM) and Hazard Operability Study (HAZOP). A graphical MFM model is introduced in NFMA by decomposing goals, functions and components, to descript flows of mass and energy of process system as basis of this model. According to the MFM reasoning rules, HAZOP investigates function nodes and deviations to identify the failure modes. Finally, the benefits and feasibility of NFMA are investigated with a case study of gathering system.

Keywords: MFM; HAZOP; Gathering system; Failure mode analysis

1. Introduction

Gathering system is a typical representative of complex heterogeneous industrial system, which is not only an important oilfield production facility system for gathering and transporting oil and gas but also a key section to realize the function of oil and water separation. Due to the variability among equipment operation personnel and site environment, it is very important to research the effects of failures' impacts on other parts of the system when some components' failures occur. Failure mode analysis, or FMA for short, is to find all possible faults that may happen in a system and to discover effects or causality based on the correlations among faults. Traditionally, some basic methods have been studied for analyzing the cause–effect of failure modes. The classical procedure is failure mode and effect analysis (FMEA) to analyze potential failure modes within a system for classification by the severity and likelihood of the failures (Tweeddale, 2003; Dussalut, 1984). To give a more logical reasoning between component faults and consequences, the fault tree analysis (FTA) is used to quantify more complex process failures (Pfleeger and Atlee, 2006; Batzias, 2004). Another method is Goal Tree-Success Tree method (GTST) to model deep knowledge about complex industrial systems, particularly for the matter of fault diagnosis illustrating by the goal tree of system functions and the success tree of the physical structure and the relationships among variables (Modarres, 1993). However these methodologies suffer from following problems:

a) It is difficult to detect several failures at the same time and find all possible ways a component may fail even though these models on the purpose of searching for all possibilities.
b) Because of manual analysis based on personal knowledge and experiences of experts, thus it is likely to miss important scenarios along with analysis.
c) If some processes being improved or equipment replaced in a system, it is urgent to ensure whether the existing identified possible faults are still valid. However, obviously, this question is difficult to be answered; it may require the whole analysis to be done once again.
d) Without reasoning rules, it is harder to reveal the coupling among failure modes and figure out which component faults can interact to be available for achieving system functions. Thereby, operators could fail to clarify the root causes of failure situation.

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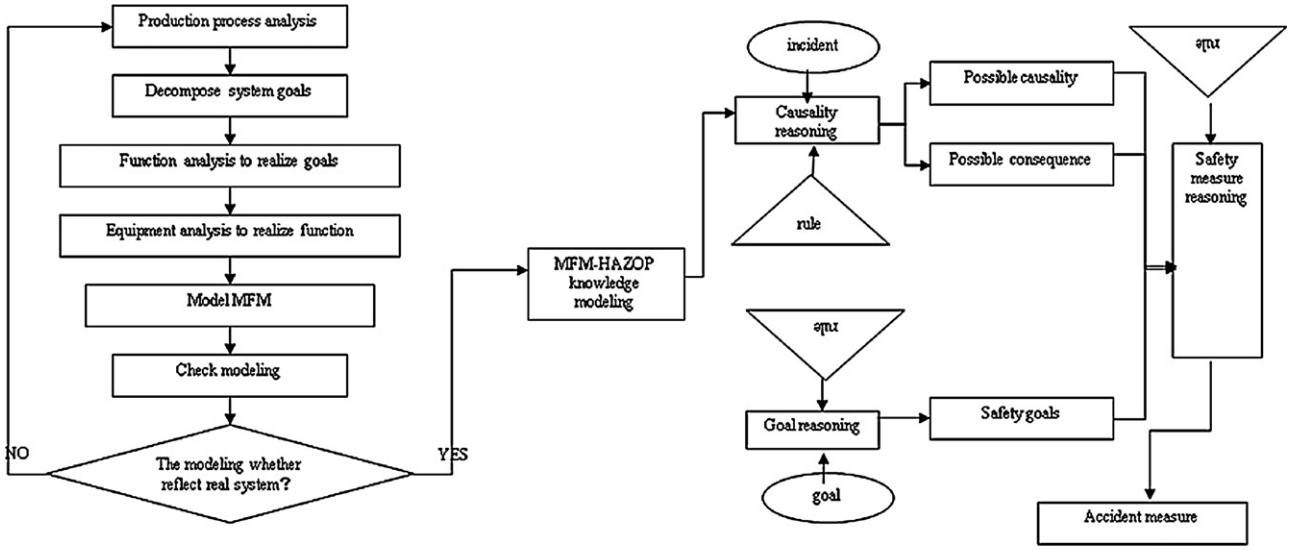

Fig. 1 – How to build the MFM–HAZOP model.

This article will focus on failure mode analysis using a graph theory model called multilevel flow models (MFM), which has many nice properties, such as possibility for on-line prediction of failures in real time (Öhman, 1999), combining with HAZOP study to model MFM–HAZOP (Fig. 1) and give a failure mode analysis for gathering system discussed later. For more detailed discussion of related work and their relations to MFM–HAZOP (Dahlstrand, 2000; Larsson, 1992).

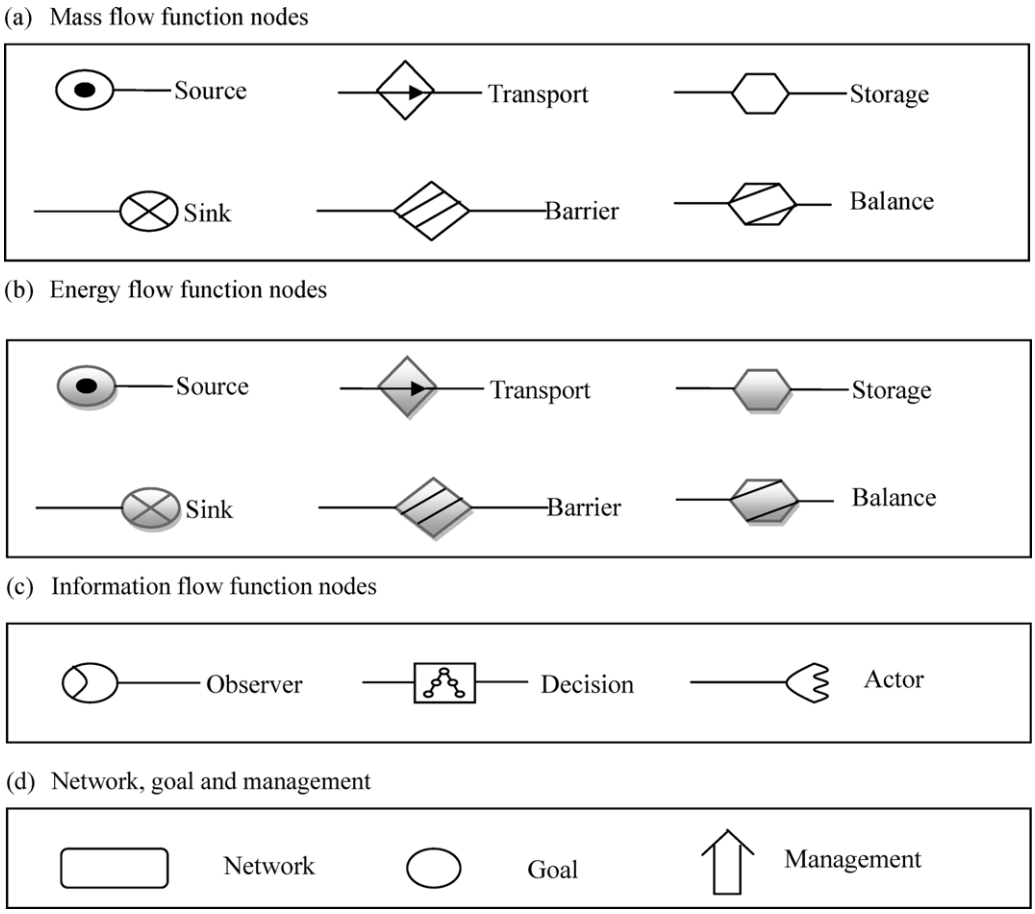

Fig. 2 – MFM symbols for functions.