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FAULT LOCATOR OF AN ALLYL CHLORIDE PLANT

Process safety analysis, which includes qualitative fault event identification, the relative frequency and event probability functions, as well as consequence analysis, was performed on an allye chloride plant. An event tree for fault diagnosis and cognitive reliability analysis, as well as a troubleshooting system, were developed. Fuzzy inductive reasoning illustrated the advantages compared to crisp inductive reasoning. A qualitative model forecast the future behavior of the system in the case of accident detection and then compared it with the actual measured data. A cognitive model including qualitative and quantitative information by fuzzy logic of the incident scenario was derived as a fault locator for an allyl chloride plant. The obtained results showed the successful application of cognitive dispersion modeling to process safety analysis. A fuzzy inductive reasoner illustrated good performance to discriminate between different types of malfunctions. This fault locator allowed risk analysis and the construction of a fault tolerant system. This study is the first report in the literature showing the cognitive reliability analysis method.

Methods for analyzing system safety and the synthesis methods for the construction of fault tolerant systems are of elementary importance for equipment in the chemical industries.

Process safety analysis begins with plant, materials and environment definition. It includes system components, topology, input and output attributes, state variables, behavior rules and initial scenarios. The control features are qualitative variable description and logic rules for manipulating variable values between systematic states [1–3]. The goal of process safety analysis is to capture the benefits of common sense reasoning about a process malfunction phenomenon as displayed in human behavior. The study of fault detection and diagnostics is concerned with designing a system that can assist the human operator in detecting and diagnosing equipment faults in order to prevent accidents. Risk analysis includes hazard identification, frequency and probability analysis, consequence analysis and hazard cost analysis. Hazard identification methods can be used in different ways to model part of the incident scenario leading to a possible accident. A systematic cause event analysis gives results which are summarized in the form of a fault three. It follows the structure of a generic fault tree up to the release of materials, chemicals and of an event tree from this point to the impact of the release on people, plants and the environment [4–7]. Frequency and probability analysis involves the frequency values of hazards, the magnitude identification of each hazard and the development of sound criteria for quantification of the logic tree. All hazards, major and minor, need to be included. The relationship between hazard and risk must be defined [8]. Consequence modeling develops a troubleshooting system and formalizes hazard reporting as a learning tool and creates recommendations to correct the hazard.

A number of methods for safety analysis were worked out based on the classical results of Boolean algebra and the probability theory. Based on the fundamental concept of the "membership function" introduced by Zadeh [9,10] a comprehensive methodology for handling fuzzy problems was worked out in the last two decades [7,11–16]. A fuzzy theory for fault tree and reliability analysis was given in contributions by Singer [17].

A fuzzy inductive reasoner demonstrates an enhancement over a crisp inductive reasoner. While a crisp reasoner sometimes has difficulties to discriminate between different types of malfunctions, a fuzzy inductive reasoner is able to discriminate between different types of malfunctions. Also, a fuzzy inductive reasoner is able to identify malfunctions in a shorter span of simulated time on the quantitative model than its crisp counterpart [18–20].

So many accidents have been caused by operator's misjudgments or misoperations that there is a need to develop a system which can also suggest appropriate action to be taken when a hazard occurs. Hazard cost analysis of an allyl chloride plant creates a resource allocation model by linking risks [7,21,22].

A fault locator and reliability analysis were developed by fuzzy modeling for an allyl chloride plant in this paper. The fault tree model and reliability analysis derived qualitative and quantitative information of the process safety analysis. These results demonstrated the successful application of dispersion modeling for process safety.

FAULT EVENT ANALYSIS

The fault events of a system are in the first istance generally formulated in an IF–THEN form. This can be immediately reformulated using the operators AND, OR and NOT in Boolean form, if one can assume that the

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primary events have only two states: existence and non–existence.

To overcome the first difficulty, new primary variables should be chosen fulfilling the criterion of mutual exclusivity. If this is not possible by common sense considerations, a more cumbersome technique is needed, such as the tabular method, the Karnaugh map technique [17]. The second difficulty that the Boolean expressions do not appear in their simplest form can be overcome by systematic simplification of the intermediary results using the known equivalence relations of Bollean algebra.

Starting with the basic variables and their interrelations, the qualitative event model of the system can be formulated successively in the form of Boolean functions. To make the qualitative model quantitative, the independent variables should be replaced by the relative frequencies of the events p_i and the Boolean operators AND and OR should be replaced by the algebraic functions (operators) AND (p_1, p_2, p_3, ... p_n) and OR (p_1, p_2, p_3, p_n) producing the output frequency p_y from the input frequencies p_1, p_2, p_3, ... p_n.

The negated Boolean variables are replaced by the relative frequencies. The term relative frequency should be used instead of the term event probability. A probabilistic variable must be fulfill this requirement:

$$\overline{p}_1 = 1 - p_i \tag{1}$$

The AND (p_1, p_2, p_3, ... p_n) operator assigns the valure p_y for n input frequencies

$$p_y = \prod_{i=1}^{n} p_i \tag{2}$$

analogously the OR (p_1, p_2, p_3, ... p_n) operator should be:

$$p_y = \sum_{i=1}^{n} p_i \tag{3}$$

Expression (2) does not fulfill the requirement that the relative frequencies must lie in the interval $0 \le p_i \le 1$. Therefore equation (2) is transformed using Mogran's rule [23]

$$p_1 + p_2 + p_3 \ldots p_n = \overline{p}_1 \times \overline{p}_2 \times \overline{p}_3 \times \ldots \overline{p}_n$$

in the form:

$$p_y = 1 - [(1-p_1)(1-p_2)\ldots(1-p_n)] = 1 - \prod_{i=1}^{n} (1-p_i) \tag{4}$$

Expressions (1), (2) and (3) for the concatenation of the event frequencies in the fault tree can be viewed as satisfactory founded if the p_y's have crisp values. However, for rate natural phenomena and man made systems this assumption is not always allowable. It is, therefore, natural to consider the values of the event frequencies p_i as fuzzy numbers.

A FUZZY SET APPROACH TO FAULT EVENT MODELING

A fuzzy number is a continous fuzzy set of the universe U with the convex membership function $\mu(x)$ fulfilling the following requirement [13,17].

$$\max_{x \in U} \mu(x) = 1 \tag{5}$$

The fuzzy value of the relative event frequency must fulfill the requirements $0 \le p_i \le 1$ similarly to the crisp value. The membership function of the event frequency can have a great variety of forms. The width of the membership function is the measure of the spread of the frequency value. If the spread is infinitely small, the value of the fuzzy p_i is identical to that of the crisp one. After considering the relative frequencies of the basic event as fuzzy numbers, a further step must be taken, laws for the calculation of the induced event frequencies must be defined. We assumed that the crisp algebraic operators (1), (2), (3) and (4) should be formally applicable for the fuzzy domain as well, with the difference that the algebraic multiplication and additions in the expressions should be replaced by the appropriate fuzzy operations.

The extension of addition and multiplication in the fuzzy domain can be realized according to the extension principle [10].

The extension of the real function $y = \phi(x_1, x_2, x_3, \ldots x_n)$ of the real variables $(x_1, x_2, x_3 \ldots x_n)$ in the fuzzy domain gives a fuzzy function $\overline{y} = \phi(\overline{x}_1, \overline{x}_2, \overline{x}_3, \ldots \overline{x}_n)$ of the fuzzy variables $(\overline{x}_1, \overline{x}_2, \overline{x}_3 \ldots \overline{x}_n)$ with the membership function:

$$\mu(t) = \sup_{t=\phi} (s_1, s_2, \ldots s_n) \times \min [\mu_{\overline{x}_1}(s_1), \mu_{\overline{x}_2}(s_2), \ldots \mu_{\overline{x}_n}(s_n)] \tag{6}$$

where $\mu_{\overline{x}_1}(s_1)$, $\mu_{\overline{x}_2}(s_2)$, $\ldots \mu_{\overline{x}_n}(s_n)$ are the membership functions of the fuzzy variables $\overline{x}_1, \overline{x}_2, \ldots \overline{x}_n$.

Based on this theorem, algorithms for fuzzy addition and multiplication can be derived for all sorts of membership functions with limited numbers of discontinuities. Such algorithms are relatively complicated and time consuming for numerical calculation. Considerable simplification can be achieved if one approximates the membership functions by simple standard functions.

The original membership function $\mu(x)$ was replaced by the monotonically increasing and monotonically decreasing function $L_f(x)$ and $R(x)$, respectively, intersecting each other at the maximum of the original membership function.

The approximate membership function, L_f–R type function, has the form:

$$\mu(x) = \begin{cases} L_f(m-x)/\alpha & \text{for } x \le m \text{ and } \alpha > 0 \\ R(x-m)/\beta & \text{for } x \ge m \text{ and } \beta > 0 \end{cases} \tag{7}$$

where m is the maximum value of the fuzzy number. Using the relative frequencies of the events in a fault tree as a fuzzy numbers, each of them will be defined by an L_f–R function of the type (7), α and β are the left and right spreads, L_f and R are the appropriately chosen functions (m–x)/α and (x–m)/β, respectively. For the sake of simplicity, the L_f–R type approximates of the fuzzy numbers will be denoted by the triple $(m, \alpha, \beta)_{L_f,R}$.

Expression (7) can also be considered as the definition of the fuzzy number $\bar{m}$ corresponding to the crisp number m. With the notation $(m, \alpha, \beta)_{L_f,R}$, the extended algebraic operations on fuzzy numbers deduced according to the extension principle, can be formulated as follows:

Changing of sign:

$$-(m,\alpha,\beta)_{L_f,R} = (-m,\alpha,\beta)_{R,L_f} \tag{8}$$

Addition:

$$(m,\alpha,\beta)_{L_f,R} + (n,\gamma,\delta)_{L_f,R} = (m+n,\ \alpha+\gamma,\ \beta+\delta)_{L_f,R} \tag{9}$$

Subtraction:

$$(m,\alpha,\beta)_{L_f,R} - (n,\gamma,\delta)_{L_f,R} = (m-n,\ \alpha-\gamma,\ \beta-\delta)_{L_f,R} \tag{10}$$

Multiplication

$$(m,\alpha,\beta)_{L_f,R} \times (n,\gamma,\delta)_{L_f,R} \cong (mn,\ n\gamma+n\alpha, m\delta+n\beta)_{L_f,R} \tag{11}$$

Expression (11) is an approximation valid for relatively small spreads. A more appropriate formula for large spreads is:

$$(m,\ \alpha,\ \beta)_{Lf,R} \times (n,\ \gamma,\ \delta)_{L_f,R} \cong (mn,\ m\gamma + m\alpha - \alpha\gamma,\ m\delta + n\beta + \beta\delta)_{L_f,R} \text{ if } m > 0, n > 0 \tag{12}$$

The possibilities membership function of the fuzzy AND (p_1, p_2, ... p_n) and OR (p_1, p_2, ... p_n) operators can be obtained by considering the variables in Eqs. (1), (2) and (4) as fuzzy variables and substituting the algebraic operator with the fuzzy operations. The fuzzy form of the AND (p_1, p_2, ... p_n) is operator

$$\text{ANF}\ (\bar p_1,\ \bar p_2,\ \ldots\ \bar p_n)$$

$$p_y = \text{ANF}(\bar p_1,\ \bar p_2,\ \ldots\ \bar p_n) = \prod_{i=1}^{n} \bar p_1 \tag{13}$$

Π denotes the fuzzy multiplication.

The fuzzy form of the OR (p_1, p_2, ... p_n) operator ORF $(\bar p_1, \bar p_2, \ldots \bar p_n)$ is defined

$$\bar p_y = \text{ORF}\ (\bar p_1,\ \bar p_2,\ \ldots\ \bar p_n) = 1 - \prod_{i=1}^{n} (1 - \bar p_i) \tag{14}$$

FAULT TREE DIAGNOSIS AND PROCESS SAFETY ANALYSIS OF AN ALLYL CHLORIDE PLANT

The chemical plant consists of a reactor, a pump, a compressor, two columns, a drier/scrubber, preheater, four coolers and two heaters. Each process unit and stream of the process has a frame associated with it in which fundamental information is placed (Figure 1). Propylene is fed at 15.5°C and 1360 KPa and mixed with a recicle stream containing mostly unreacted propylene [24].

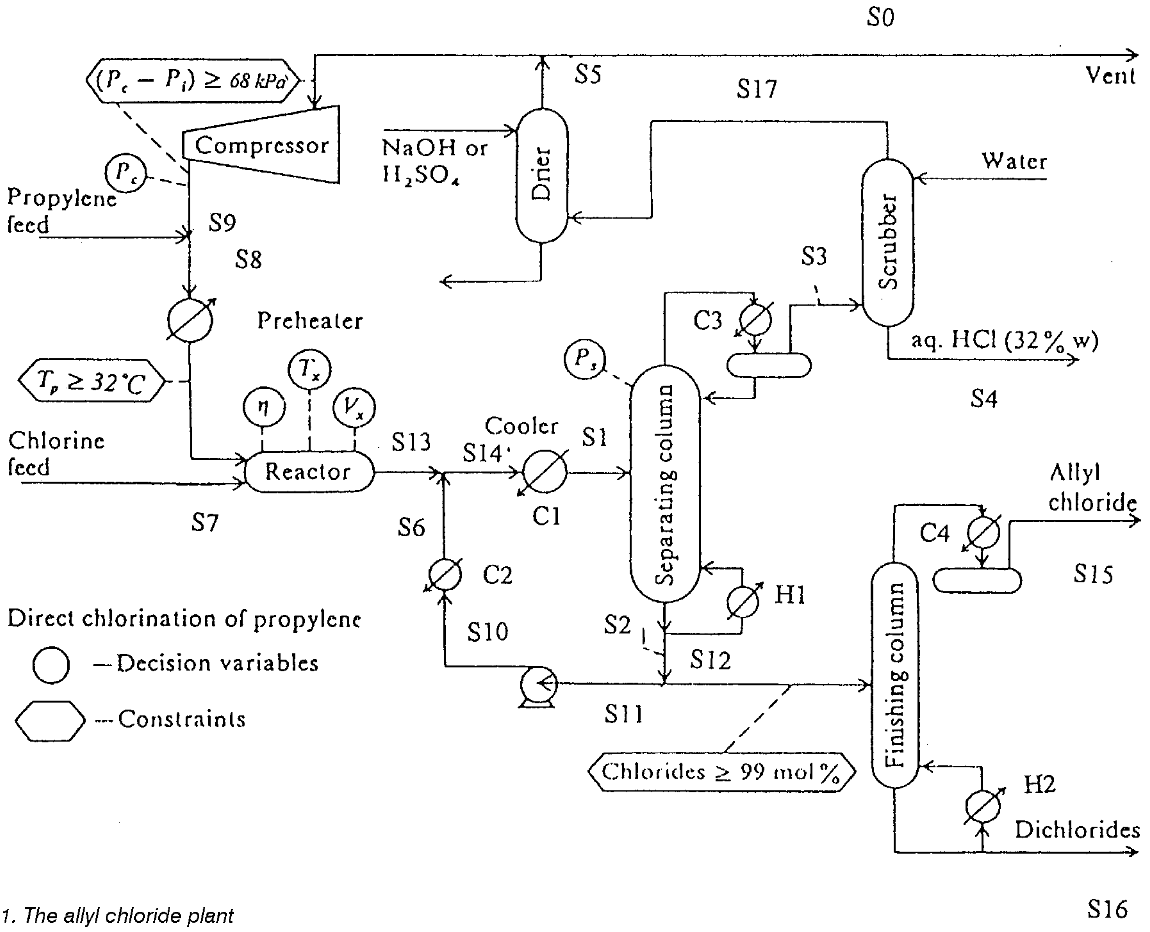

Figure 1. The allyl chloride plant

The reaction rate expression is:

$$r_k = K_k p_{jx}^{l} p_{CL_2}^{l}$$

$$K_k = A_k \exp\left[-B_k / (T + 460)\right] \qquad (15)$$

Three reactions were involved, k=1,2,3 where r_k is the reaction rate for reaction k, K_k is the rate constant, p_{jx} is the partial pressure of the reactant, p_{CL_2} is the partial pressure of chlorine A_k and B_k are constants and T is temeprature. The inlet ratio of propylene/chlorine was selected as the manipulated variable. The objective was to operate as close to the maximum product yield.

The process flow diagram (PFD) for the allyl chloride cynthesis is shown in Figure 1. Figure 1 shows the material and energy stream network, equipment, operational parameters, products and utilities. PFD decomposition involves selecting the appropriate tear streams or process units and the transmission of information.

The system can diagnose for causes of faults associated with the state variables pressure, flow rate and temperature. The qualitative variables are described in three discrete values low, medium, high [3]. For diminishing the losses, a systematic cause–event analysis was made and the results were summarized in the form of a fault tree. The attributes of the model were chosen to be oil pressure, supply, flow and resistance. Supply was described in two descrete values (present, absent). The states of the equipment were described in qualitative terms such as closed, open, failed, blocked and leak. The following faults were considered: blockage, leakage, malfunction or misoperation. The study of fault detection and diagnostics is concerned with designing a system that can assist the human operator to detect and diagnose equipment faults in order to prevent accidents [7].

Faults and actions should correspond to changes in the state of equipment and deviations in the system variables. When leakage occurs in the upstream Unit–USU, the influence of leakage on USU can not be removed by closing the equipment. However, when leakage occurs in the downstream unit, DSU, the influence of leakage on DSU can be removed by closing the equipment.

The derived qualitative fault tree for the allyl chloride plant is shown in Figure 2. It would be equivalent to the following system of Boolean expressions (16). This system represents the qualitative events model expressed by classical logic algebra. M, B and L are independent Boolean variables representing the basic events malfunction, blockage and leakage, respectively. RC denotes the reactor, SDC the distillation separation column, FDC the finishing distillation column, SB/D denotes scrubber/drier, P the pump, S the stream, CPS the compressor, H and PH are the heater and preheater, respectively. The frequencies of the basic events are given in Table 1. Induced events are described in Table 2. The quantitative event model can be obtained from Eqs. (16) by substituting the Boolean variables by the appropriate event frequencies and instead of using Boolean operators by applying probability frequency operators.

Table 1. Frequencies of the basic events

Event code	Middle frequencly*	Description
M(H1)	0.0003	Malfunction of heater H1
M(H2)	0.0003	Malfunction of heater H2
M(PH)	0.0003	Malfunction of the preheater
M(C1)	0.0002	Malfunction of cooler C1
M(C2)	0.0002	Malfunction of cooler C2
M(C3)	0.0002	Malfunction of cooler C3
M(C4)	0.0002	Malfunction of cooler C4
M(P)	0.0004	Pump malfunction
S(W)	0.0011	Water supply
S(P)	0.0015	Propylene supply
S(CH)	0.0015	Shlorine supply
S(D)	0.0011	Dry tool supply
B0	0.0009	Blackage of stream S0
L0	0.0004	Leakage of stream S0
B1	0.0009	Blockage of stream S1
L1	0.0004	Leakage of stream S1
B2	0.0009	Blockage of stream S2
L2	0.0004	Leakage of stream S2
B3	0.0009	Blockage of stream S3
L3	0.0004	Leakage of stream S3
B4	0.0009	Blockage of stream S4
L4	0.0004	Leakage of stream S4
B5	0.0009	Blockage of stream S5
L5	0.0004	Leakage of stream S5
B6	0.0009	Blockage of stream S6
L6	0.0004	Leakage of stream S6
B7	0.0009	Blockage of stream S7
L7	0.0004	Leakage of stream S7
B8	0.0009	Blockage of stream S8
L8	0.0004	Leakage of stream S8
B9	0.0009	Blockage of stream S9
L9	0.0004	Leakage of stream S9
B10	0.0009	Blockage of stream S10
L10	0.0004	Leakage of stream S10
B11	0.0009	Blockage of stream S11
L11	0.0004	Leakage of stream S11
B12	0.0009	Blockage of stream S12
L12	0.0004	Leakage of stream S12
B13	0.0009	Blockage of stream S13
L13	0.0004	Leakage of stream S13
B14	0.0009	Blockage of stream S14
L14	0.0004	Leakage of stream S14
B15	0.0009	Blockage of stream S15
L15	0.0004	Leakage of stream S15
B16	0.0009	Blockage of stream S16
L16	0.0004	Leakage of stream S16
B17	0.0009	Blockage of stream S17
L17	0.0004	Leakage of stream S17

*The unit of the middle frequency is the number of faults/10^4 hours

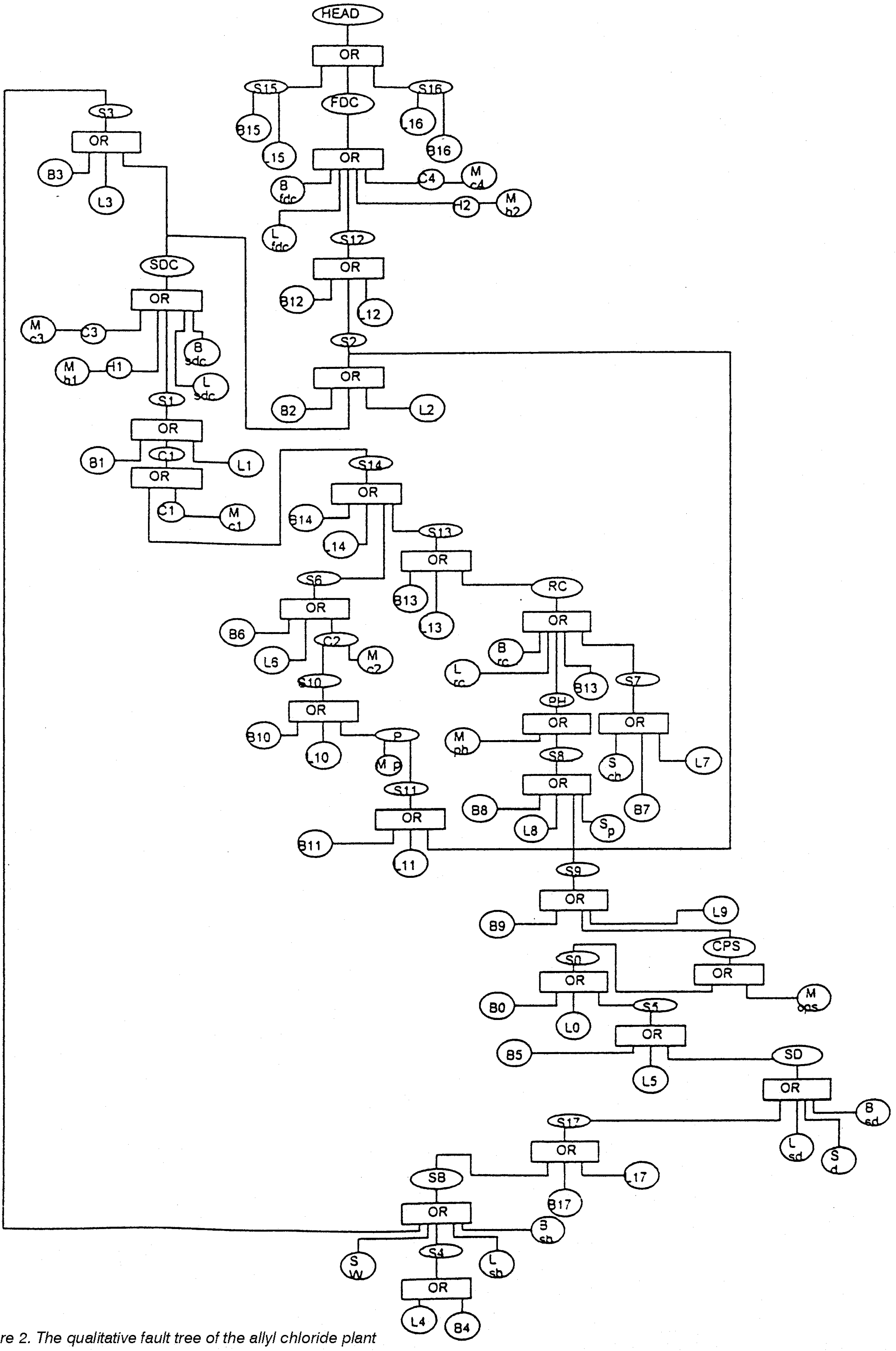

Figure 2. The qualitative fault tree of the allyl chloride plant

Table 2. Complex event description

Event code	Description
HEAD	Unstable allyl chloride production
S15	Improper allyl chloride stream
S16	Improper dichloride stream
FDC	Finishing distillation column failded
SDC	Separation distillation column failed
RC	Reactor failed
SB	Scrubber failed
SD	Drier failed
CPS	Compressor failed
P	Pump failed
C1	Cooler C1 failed
H1	Heater H1 failed
C2	Cooler C2 failed
H2	Heater H2 failed
C3	Cooler C3 failed
C4	Cooler C4 failed
PH	Preheater failed
S14	Improper stream S14
S13	Improper stream S13
S12	Improper stream S12
S11	Improper stream S11
S10	Improper stream S10
S9	Improper stream S9
S8	Improper stream S8
S7	Improper stream S7
S6	Improper stream S6
S5	Improper stream S5
S4	Improper stream S4
S3	Improper stream S3
S2	Improper stream S2
S1	Improper stream S1
S0	Improper stream S0

The qualitative model event equations (16)

$HEAD = FDC \cup S15 \cup S16$
$FDC = S12 \cup M(C4) \cup M(H2) \cup B(FDC) \cup L(FDC)$
$S15 = B15 \cup L15$
$S16 = B16 \cup L16$
$S12 = B12 \cup L12 \cup S2$
$SDC = S1 \cup M(C3) \cup M(H1) \cup B(SDC) \cup L(SDC)$
$S4 = B4 \cup L4$
$S3 = SDC \cup B3 \cup L3$
$S1 = B1 \cup L1 \cup C1$
$C1 = S14 \cup M(C1)$
$S14 = B14 \cup L14 \cup S13 \cup S6$
$S13 = RC \cup B13 \cup L13$
$S6 = B6 \cup L6 \cup C2$
$C2 = M(C2) \cup S10$
$S10 = B10 \cup L10 \cup P$
$P = S11 \cup M(P)$
$S11 = B11 \cup L11 \cup S2$
$S2 = SDC \cup B2 \cup L2$
$RC = S7 \cup PH \cup B13 \cup B(RC) \cup L(RC)$
$PH = S8 \cup M(PH)$
$S9 = B9 \cup L9 \cup CPS$
$S7 = B7 \cup L7 \cup S(CH)$
$S8 = B8 \cup L8 \cup S(P) \cup S9$
$CPS = S0 \cup M(CPS)$
$S0 = B0 \cup L0 \cup S5$
$S5 = SD \cup B5 \cup L5$
$S17 = SB \cup B17 \cup L17$
$SD = S17 \cup B(SD) \cup L(SD) \cup S(D)$
$SB = B(SB) \cup L(SB) \cup S3 \cup S4 \cup S(W)$

RELIABILITY ANALYSIS

The quantitative realibility model, derived by Eqs.(1)–(4), is given by expression (17). The system of twenty algebraic equations can be easily solved for all unknown frequencies using the values of the frequencies of the basic events given in Table 1. Table 1 describes the middle values of the frequencies of the basic events. The crisp values of the basic frequencies figuring in Table 1 should be considered as the best estimated. The unit of the middle frequency of the basic events in the number of faults per 10^4 hours.

For the fuzzy analysis of the event tree, the Boolean operators will be replaced by the fuzzy frequency operators ORF (...) and ANF (...). The expresions (18) were obtained by denoting the fuzzy event frequencies with the event codes in Tables 1 and Table 2 (18). The spread around the best estimates was assumed for the numerical evaluation of Eqs. (18).

Sistematic cause event analysis was performed by dispersion modeling and qualitative simulation through fuzzy inductive reasoning. Continuous signals could then be regenerated from the resulting qualitative variables that could subsequently be used as inputs to other quantitative or qualitative submodels.

Fuzzy inductive reasoning demonstrates an enhancement over crisp inductive reasoning. Consequently, the number of errors in the qualatitatively predicated states was reduced from one third to less than one tenth, and the error chain produced by those errors almost vanished. While the crisp reasoner sometimes had difficulties to discrimate between different types of malfunctions, the fuzzy inductive reasoner was able to discriminate clearly and unambigously between different types of malfunctions. Also, the fuzzy inductive reasoner was able to identify malfunctions in a shorter span of simulated time on the qualitative model than its crisp counterpart.

The Reliability Model Equations (17)

$p_{HEAD} = 1 - (1 - p_{FDC})\,(1 - p_{S15})\,(1 - p_{S16})$
$p_{FDC} =$
$= 1 - (1 - p_{S12})\,(1 - p_{M(C4)}\,(1 - p_{M(H2)})\,(1 - p_{B(FDC)})\,(1 - p_{L(FDC)})$
$p_{S16} = 1 - (1 - p_{B16})\,(1 - p_{L16})$
$p_{S15} = 1 - (1 - p_{B15})\,(1 - p_{L15})$
$p_{S12} = 1 - (1 - p_{B12})\,(1 - p_{L12})\,(1 - p_{S2})$

$p_{SDC} =$
$1-(1-p_{S1})\,(1-p_{M(C3)})\,(1-p_{M(H1)})\,(1-p_{B(SDC)})\,(1-p_{L(SDC)})$
$p_{S4} = 1-(1-p_{B4})\,(1-p_{L4})$
$p_{S3} = 1-(1-p_{SDC})\,(1-p_{B3})\,(1-p_{L3})$
$p_{S1} = 1-(1-p_{B1})\,(1-p_{L1})\,(1-p_{C1})$
$p_{C1} = 1-(1-p_{S14})\,(1-p_{M(C1)})$
$p_{S14} = 1-(1-p_{B14})\,(1-p_{L14})\,(1-p_{S13})\,(1-p_{S6})$
$p_{S13} = 1-(1-p_{RC})\,(1-p_{B13})\,(1-p_{L13})$
$p_{S6} = 1-(1-p_{B6})\,(1-p_{L6})\,(1-p_{C2})$
$p_{S10} = 1-(1-p_{B10})\,(1-p_{L10})\,(1-p_{p})$
$p_{S11} = 1-(1-p_{B11})\,(1-p_{L11})\,(1-p_{S2})$
$p_{p} = 1-(1-p_{M(p)})\,(1-p_{S11})$
$p_{C2} = 1-(1-p_{M(C2)})\,(1-p_{S10})$
$p_{S2} = 1-(1-p_{B2})\,(1-p_{L2})\,(1-p_{SDC})$
$p_{SD} = 1-(1-p_{S17})\,(1-p_{B(SD)})\,(1-p_{L(SD)})\,(1-p_{S(D)})$
$p_{SB} = 1-(1-p_{B(SB)})\,(1-p_{L(SB)})\,(1-p_{S3})\,(1-p_{S4})\,(1-p_{S(T)})$
$p_{RC} = 1-(1-p_{S7})\,(1-p_{B13})\,(1-p_{PH})\,(1-P_{B(RC)})\,(1-p_{L(RC)})$
$p_{S9} = 1-(1-p_{B9})\,(1-p_{L9})\,(1-p_{CPS})$
$p_{S7} = 1-(1-p_{B7})\,(1-p_{L7})\,(1-p_{S(CH)})$
$p_{PH} = 1-(1-p_{M(PH)}\,(1-p_{S8})$
$p_{S8} = 1-(1-p_{B8})\,(1-p_{L8})\,(1-p_{S9})\,(1-p_{S(P)})$
$p_{CPS} = 1-(1-p_{SO})\,(1-p_{M(CPS)})$
$p_{S0} = 1-(1-p_{B0})\,(1-p_{L0})\,(1-p_{S5})$
$p_{S5} = 1-(1-p_{B5})\,(1-p_{L5})\,(1-p_{D})$
$p_{S17} = 1-(1-p_{B17})\,(1-p_{L17})\,(1-p_{SB})$

The fuzzy reliability model equations (18)

HEAD= ORF(FDC, S15, S16)
S15= ORF(B15, L15)
S16= ORF(B16, L16)
FDC= ORF(S12, M(C4), M(H2), B(FDC), L(FDC))
S12= ORF(B12, L12, S2)
S2= ORF(B2, L2, SDC)
S3= ORF(B3, L3, SDC)
S4= ORF(B4, L4)
SDC= ORF(S1,M(H1), M(C3), B(SDC), L(SDC))
SD= ORF(S17, B(SD), L(SD), S(D))
S1= ORF(B1, L1, C1)
C1= ORF(M(C1), S14)
S5= ORF(B5, L5, SD)
S10= ORF(P, B10, L10)
P= ORF(M(P), S11)
S11= ORF(B11, L11, S2)
S6= ORF(B6, L6, C2)
C2= ORF(M(C2), S10)
S14= ORF(B14, L14, S13, S6)
S13= ORF(RC, B13, L13)
RC= ORF(PH, S7, B13, B(RC), L(RC))
PH= ORF(M(PH), S(8))
CPS= ORF(M(CPS), S(0))
S0= ORF(B0, L0, S5)
S8= ORF(S(P), B(8), L8, S(9))
S9= ORF(CPS, B9, L9)
S7= ORF(B7, L7, S(CH))
S17= ORF(SB, B17, L17)
SB= ORF(B(SB), L(SB), S3, S4, S(W))

A computer program was written in FORTRAN 77 and tested on a PC computer. An effective expert system was developed which generated a plant operation support system for loss prevention.

SOFT LOCATOR

The obtained soft locator was able to seek out the cause of the fault and resolve the consequences. Investigation of the cause was provided by symptom decomposition.

Knowledge based safety assessment of a process plant based on classical and fuzzy logic was performed. The fuzzy model gave alternative approaches to risk evaluation. The computer program of the procedure was written in FORTRAN 77.

This soft locator is very useful as a tool for process safety analysis and efficient plant management and can be used for fault tolerant system construction.

CONCLUSION

This paper demonstrates hazard identification, frequency and probability analysis and consequences analysis of an allyl chloride plant. The initial phase started with the development of a conceptual framework which facilitated the modular specification. The second phase started with the development of a logic framework which permited object using attributes to be linked into executable models. The qualitative fault tree and reliability models gave qualitative and quantitative information for risk assessment.

The obtained results showed the successful application of cognitive dispersion modeling in process plant risk analysis. Process safety and plant reliability analysis were considered as a loss prevention process which could be used to identify those plant equipment failure incidents that warranted detailed investigation of the cause. These results contribute to trouble recognition and classification. This work is the first report in the literature showing qualitative information decomposition into quantitative information. The obtained soft fault locator could be used for environmental protection and loss prevention.

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NOTATION

A_k – constant
B_k – constant
B – blockage
CPS – compressor
C – cooler
FDC – finishing distillation column
H – heater
K_k – chemical reaction constant
L – leakage

L_f – appropriate chosen function
M – malfunctions
m, n – crisp value
P – pump
P_{jx}, p_{CL_2}– partial pressure of reactants
p_i – relative frequency of the event
R – appropriate chosen function
RC – reactor
r – reaction rate
S – stream
SB – scrubber
SD – drier
S(CH) – chlorine supply
S(P) – propylene supply
S(D) – dry tool supply
S(W) – water supply
T – temperature, K
U – fuzzy domain
x – real variable
y – real function
$\bar{x}$ – fuzzy variable
$\bar{y}$ – fuzzy function

GREEK LETTERS

α, β, γ, δ– left and right spread
$\mu(x)$ – membership function

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IZVOD

LOKATOR GREŠKE ALILHLORIDNOG POSTROJENJA

(Naučni rad)

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Analiza bezbednosti procesa koja uključuje kvalitativnu identifikaciju otkaza, relativnu frekfenciju i verovatnosne funkcije događaja, kao i konsekventnu analizu izvedena je na postrojenju alil–hlorida. Razvijeno je stablo događaja za dijagnostiku greške i kognitivnu analizu pouzdanosti, kao i sistem za uklanjanje poremećaja. Fazi induktivno rezonovanje ilustruje prednosti u odnosu na diskretno induktivno rezonovanje. Za detekciju havarije kvalitativni model predskazuje buduće ponašanje sistema i poredi ga sa aktuelno merenim podacima. Izveden je kognitivni model koji uključuje kvalitativne i kvantitativne informacije pomoću fazi logike incidentnog scenarija, kao i lokator greške alilhloridnog postrojenja. Dobijeni rezultati pokazuju uspešnu primenu kognitivnog disperznog modelovanja na analizu bezbednosti hemijskog postrojenja. Fazi induktivno rezonovanje ilustruje dobro razdvajanje različitih vrsta greške. Lokator greške dozvoljava analizu rizika i izgradnju tolerantnog sistema na grešku. Ovaj rad je prvi izveštaj u literaturi koji pokazuje metodu analize kognitivne pouzdanosti.

Ključne reči: Kognitivni model • Kognitivna pouzdanost • Detekcija havarije • Modelovanje otkaza • Fazi rezonovanje • Predskazivanje sistema • Alilhlorid postrojenje •

Key words: Cognitive dispersion model • Loss prevention • Fault event modeling • Fuzzy forecasting •