FLUCOME 2009
10th International Conference on Fluid Control, Measurements, and Visualization
August 17–21, 2009, Moscow, Russia

DECISION SUPPORT SYSTEMS ON HAZARDS OF INDUSTRIAL EXPLOSIONS AND FUZZY LOGIC

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ABSTRACT

The progress in computing machinery enlarged greatly the human potentialities in sphere of reaching of the high-quality decisions for solving different problems. It concerns also the problems of hazards, prevention, and mitigation of explosions. The explosion prevention is one of the most difficult problems of the present-day industry and up-to-date transport. It is obvious the necessity of creating special program-technical systems. Those systems must make it possible for the reaching decision person (RDP) to construct the information technology for supporting the process of formation of decision (action, operation) in different situations. Such a system, which gives supporting for RDP in the reaching decision process, is named the decision support system (DSS). In particular the advising systems and the expert systems belong to DSS. No DSS is aimed for the full substitution of RDP, but sometimes such substitution is possible in extraordinary cases. For the constructing of DSS on the explosion-proof problems it is possible to use two kinds of mathematical models. The first model is the model of decision-making under uncertainty, it is based on the fuzzy-set theory and fuzzy logic. The second model is the model of decision-making under risk, it is based on the probability theory and the probability logic (it is almost impossible to use the classical model of decision-making under certainty because of the complexity of the process). It is proved that application of the first model is preferable for complicated industrial and transport systems. As a matter of fact a lot of parameters, which are essential for the second model, are determined under the statistics processing. And statistics for the explosive processes are absent or very imperfect in many cases. Moreover, these statistics sometimes are also fuzzy in a sense. Taking into account the foregoing, we offer rather effective methodology for constructing universal enough intellectual DSS on the explosion-proof problems under conditions of "fuzziness" in combination with application of the exact mathematical theory of combustions and explosions. Suitable DSS are constructed by us for the plants for the grain storing and processing.

Keywords: Explosion, explosion-proof problems, decision support system, fuzzy logic, statistics.

INTRODUCTION

The decision-making process is very complicated intellectual human activity. It can be defined as the selection of a course of action among several alternatives to achieve one's object.

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There are such main stages of the decision-making:

1) formulation of the problem;

2) revelation of aims;

3) forming of criteria;

4) collection of information (finding alternatives and definition of their properties);

5) choice of one or several (set of) alternatives on the base of their comparison by sample criteria;

6) estimating of the choice consequences and quality of decision;

7) if estimate is negative, then return to 1) (2), 3)).

Stages 1) – 4) are named construction of the model for decision-making, and the decision-making by itself often is equated with the choice of alternative on the stage 5). Stage 6) must confirm the truth of the accepted decision or its unacceptability. In case of negative estimate (unacceptability) of the alleged decision the feedback to stages 1) – 3), beginning with the 3d stage, is realized. The criteria may be modified. If this does not change the quality of decision, the aims of the decision-making are corrected. If this also is not suitable, the whole problem may be re-formulated. So every decision making process produces a final choice. The output can be an action or an opinion. There are different models for decision-making. Those models are [1]:

1) classical model;

2) decision-making under risk conditions;

3) decision-making under conditions of uncertainty.

Sometimes models 2) and 3) together are called the behavioural model of the decision-making.

Classical model is built on the assumption that so called payoff function is real-valued, and this function linearly regulates all outcomes. Classical model uses methods of classical mathematics or numerical methods based on classical mathematics. This is decision-making under conditions of certainty. But when our knowledge about different states of nature (medium) is not full, classical model is not valid. Choice of different alternatives in such conditions is decision-making under risk conditions or decision-making under conditions of uncertainty [1]. Decision is making under risk conditions if all possible states of nature (medium) and sharing of their probabilities are known. Theoretical base for such decisions is probability theory. Decision is making under conditions of uncertainty if all possible states of nature (medium) are known, but sharing of their probabilities is not known [1]. It's robust, quasi-rational decision that means making the best possible choice when information is incomplete. Theoretical base for such decisions are fuzzy-set theory and fuzzy logic[2]. This kind of decision-making uses uncertain estimates of experts, based on their theoretical knowledges, practical experiences, their intuition and so on. Due to the large number of considerations involved in many decisions, computer-based decision support systems (DSS) can be developed to assist decision makers in considering the implications of various courses of thinking. They can help reduce the risk of human errors.

PRINCIPLES OF THE DECISION-MAKING ON HAZARDS OF INDUSTRIAL EXPLOSIONS

The explosion prevention is (and always was) one of the most topical and most difficult problems of the present-day industry and up-to-date transport. It is obvious the necessity of creating special program-technical systems. Those systems must make it possible for the reaching decision person (RDP) to construct the information technology for supporting the process of decision-making (action, operation) in different situations. Such a system (the computer complex), which gives supporting for RDP in the reaching decision process, is named the decision support system (DSS). In particular the advising systems and the expert systems belong to DSS. No DSS is aimed for the full substitution of RDP, but sometimes such substitution is possible in extraordinary cases in the presence of reliable interface with the control object. The explosion problems are very complicated. Those problems can't be solved by classical mathematical methods or even numerical methods in great number of cases because of: a) their mathematical complexity or multivaluedness; b) absence of the reliable values of thermodynamical and/or chemical parameters. Even physical models for different explosive processes looks sometimes doubtful. Experimental data in many cases are not reliable and sometimes are even contradictory [3]. So classical models for the decision-making on hazards of industrial explosions often are not applicable. For the constructing of DSS on the explosion-proof problems it is possible to use two kinds of mathematical models. The first model is the model of decision-making under risk, it is based on the probability theory and the probability logic. The second model is the model of decision-making under uncertainty, it is based on the fuzzy-set theory and fuzzy logic. It is proved that application of the last model is preferable for complicated industrial and transport systems. As a matter of fact a lot of parameters, which are essential for the second model, are determined under the statistics processing. And statistics for the explosive processes are absent or very imperfect in many cases. Moreover, these statistics sometimes are also fuzzy in a sense. And though it is always possible to make the probability graph for conversions from the explosion-proof state to the dangerously/highly explosive one and to build up the probability matrix for such conversions in principle, the effectiveness of such methodology does not look high. Taking into account the foregoing, it's necessary to offer effective methodology for constructing universal enough intellectual DSS on the explosion-proof problems under conditions of "fuzziness". But fuzzy logic in such DSS must be used in combination with application of the exact mathematical theory of combustions and explosions and experimental data (accounting sometimes on the "fuzziness" of those data). The basis for decision-making on hazards of industrial explosions must use fuzzy estimates for such parameters as combustibility of medium, its ability for detonation, possibility of initiation (by different ways) of combustion or detonation, possibility of transition of "slow" burning to explosive deflagration or even detonation and so on. Those estimates make it possible to reach decisions on prevention or mitigation of industrial .explosions. Most of those decisions must be realized on the stage of projecting of the dangerously explosive system, but sometimes it's possible to accomplish operative measures (such as the inhibitor injection, valley on pressure and so on).

FUZZY ESTIMATES

Let us consider the fuzzy estimate of the detonation ability of media. Data base of the detonation concentration limits is done. For the estimate of the detonation ability expert indicates fuel, oxidizer, fuel concentration, geometrical form for mixture (round tube, plane canal and so on) and geometrical sizes, mixture physical parameters (initial pressure). Detonation ability of such system is expressed by fuzzy logical variable (fuzzy statement) $\tilde{A}$, which is the conjunction of three fuzzy statements, namely:

1) fuzzy logical variable $\tilde{C}$, expressing maintenance of the detonation concentration limits;

2) fuzzy logical variable $\tilde{D}$, expressing maintenance of the absence for the detonation suppressing distance;

3) fuzzy logical variable $\tilde{P}$, expressing exceeding of the initial pressure over the critical one.

That is

$$\tilde{A} = \tilde{C} \wedge \tilde{D} \wedge \tilde{P} \qquad (1)$$

Universe of discourse (universal set, basical set, basical scale) for fuzzy logical variable $\tilde{C}$ is set of values for the fuel volumetric concentration C , expressed by percentage ($0 \le C \le 100$). The characteristic function μ_C for fuzzy logical variable $\tilde{C}$ is trapezoidal (Fig.1), expressed by formula

$$\mu_C = \begin{cases} \dfrac{C}{LCDL}, npu\ 0 \le C \le LCDL \\ 1\ , npu\ LCDL \le C \le UCDL \\ 1 - \dfrac{C - UCDL}{100}, npu\ UCDL \le C \le 100 \end{cases} \qquad (2)$$

where LCDL is lower concentration detonation limit, UCDL is upper concentration detonation limit.

Value of μ_C defines for the system its degree of the belonging to the fuzzy subset $\tilde{A}_C$ of the systems which are able for detonation by the fuel concentration. It is a fuzzy subset of the accurate set of all possible systems of such type with specified fuel and oxidizer U. When $\mu_C = 1$, system may be estimated as undoubtedly able for detonation by the fuel concentration. In the case $\mu_C = 0$, system is estimated as undoubtedly disabled for detonation.

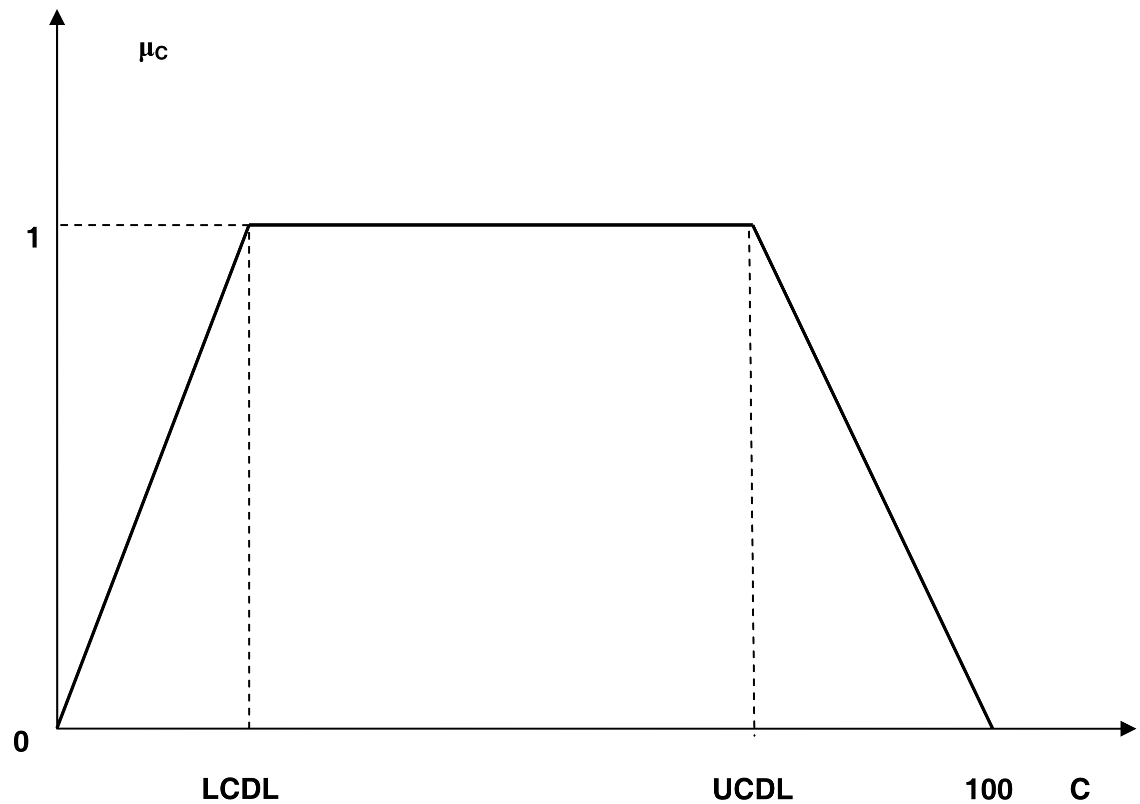

Fig. 1. The characteristic function μ_C for fuzzy logical variable $\tilde{C}$.

Universe of discourse for fuzzy logical variable $\tilde{D}$ is set of values for the canal width or the tube diameter d (d $\geq$ 0). The characteristic function μ_D for fuzzy logical variable $\tilde{D}$ is piecewise-linear (Fig. 2), expressed by formula

$$\mu_D = \begin{cases} \dfrac{d}{d_{cr}}, npu\ 0 \le d \le d_{cr} \\ 1\ , npu\ d_{cr} \le d \end{cases} \qquad (3)$$

Value of d_{cr} is less than the detonation cell size.

Value of μ_D defines for the system its degree of the belonging to the fuzzy subset $\tilde{A}_D$ of the systems which are able for detonation by the geometry of walls. It is a fuzzy subset of the accurate set of all possible systems of such type with specified fuel and oxidizer and also with specified geometry of walls U_1 ($\tilde{A}_D \tilde{\subset} U_1 \subset U$). When $\mu_D = 1$, system may be estimated as undoubtedly able for detonation by the geometry of walls. In the case $\mu_D = 0$, system is estimated as disabled for detonation.

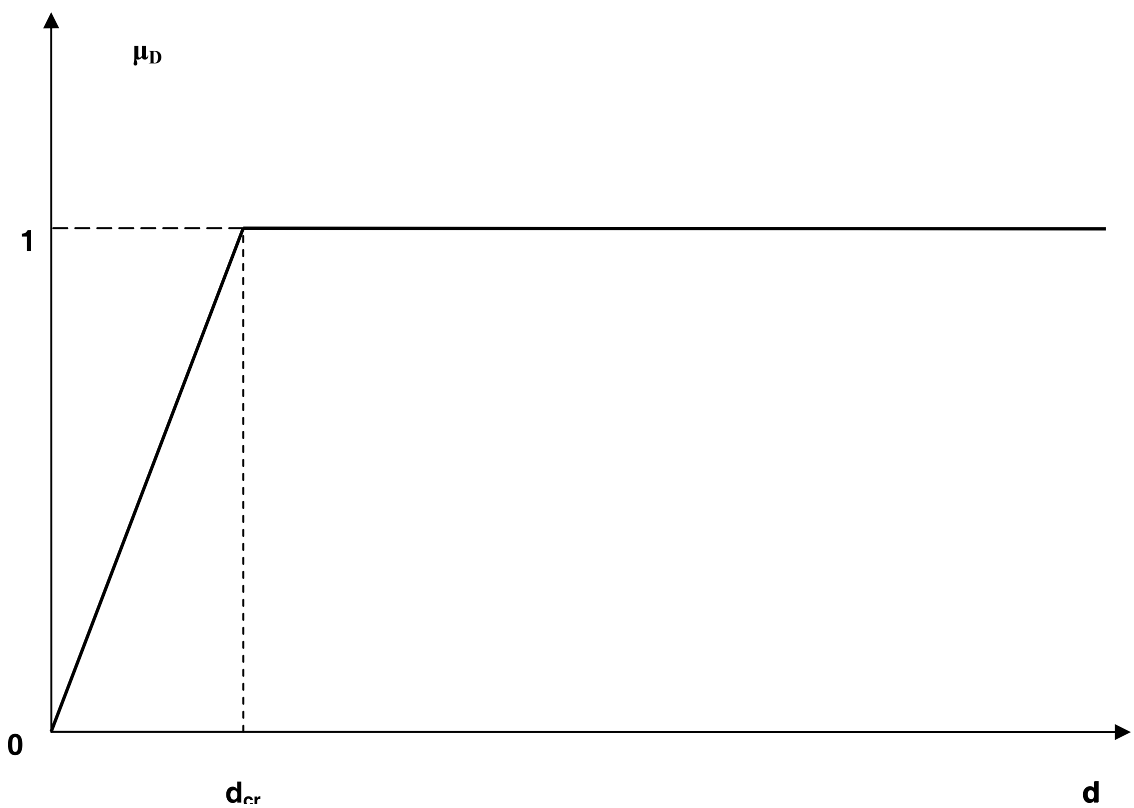

Fig. 2. The characteristic function μ_D for fuzzy logical variable $\tilde{D}$.

Finally, universe of discourse for fuzzy logical variable $\tilde{P}$ is set of values for the initial pressure p.

The characteristic function μ_P for fuzzy logical variable $\tilde{P}$ is piecewise-linear (Fig. 3), expressed by formula

$$\mu_P = \begin{cases} \dfrac{p}{p_{cr}}, npu\ 0 \le p \le p_{cr} \\ 1\ , npu\ p_{cr} \le p \end{cases} \qquad (4)$$

Parameter p_{cr} is the minimal initial pressure, when detonation is possible.

Value of μ_P defines for the system its degree of the belonging to the fuzzy subset $\tilde{A}_P$ of the systems which are able for detonation by the initial pressure. It is a fuzzy subset of the accurate set of all possible systems of such type with specified fuel and oxidizer and also with specified geometry of walls initial pressure U_2 ($\tilde{A}_P \tilde{\subset} U_2 \subset U$). When $\mu_P = 1$, system may be estimated as undoubtedly able for detonation by the initial pressure. When $\mu_P = 0$, system is estimated as disabled for detonation.

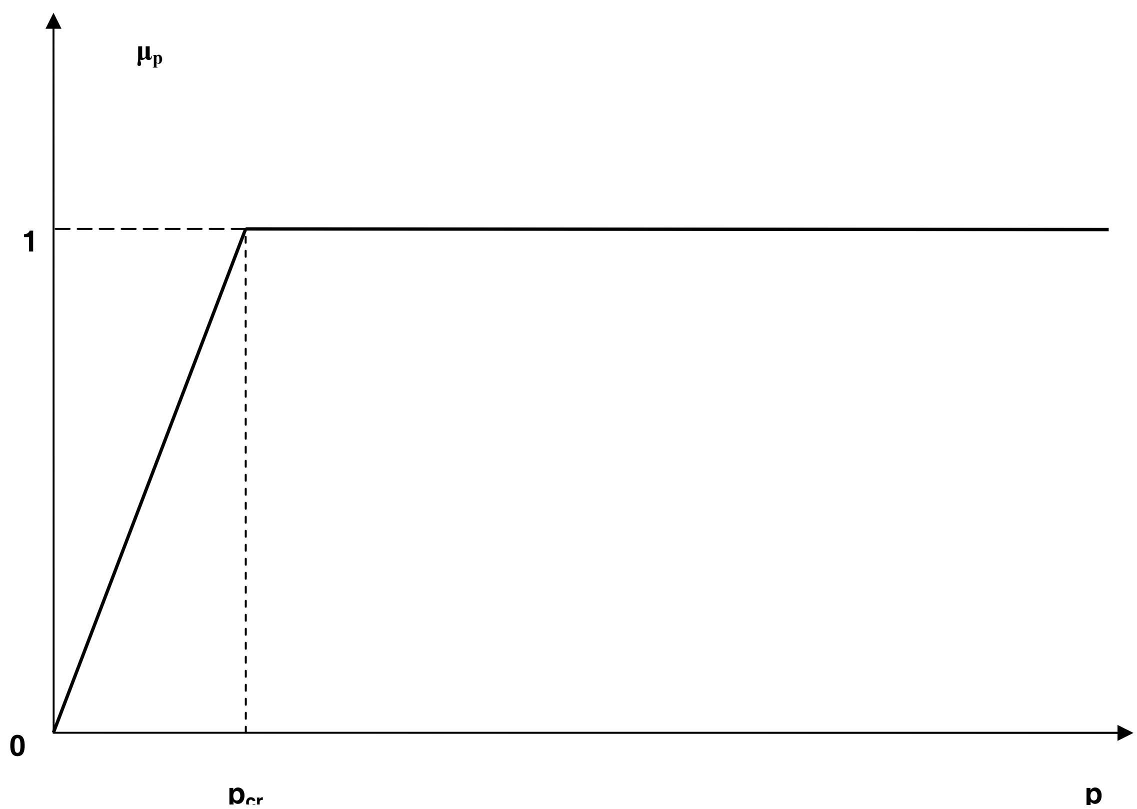

Fig. 3. The characteristic function μ_P for fuzzy logical variable $\tilde{P}$.

CONCLUSIONS

Given above example illustrates fuzzy estimates for hazards of explosions. Such estimates are the basis for the decision-making process. Suitable DSS are constructed by us for the plants for the grain storing and processing on such principles.

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