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MODELLING AND ESTIMATION OF TECHNOGENIC HAZARD AT THE STAGE OF ITS ORIGIN

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An effective means of the solution of technogenic safety problems are the specialized systems for the analysis and prediction of risk. The basis of such systems is the complex of methods which was called "Probabilistic safety assessment» (PRA) [2, 3, 4]. The logic-probabilistic methods – «Fault Tree» (FT) and «Event Tree» (ET) are used in PRA. The FT and ET methods allow to evaluate probabilities of accidents on the basis of information about the probabilities of elementary undesirable events [1, 5, 6]. The similar events are called Basic Events (BE). BE represents the failures of separate element of PHO, errors of staff and separate environmental influences. Thus, problems of PRA are connected to the problem of BE probabilities estimation.

For an estjmation of BE probabilities the method of formalized description of situations and the influence of situations on originating BE probability is designed. The method was named as "Method of Expert Assessing Scales" (MEAS) [7, 8, 9].

MEAS enables: to create the informational base for hazard assessment; - to calculate estimations of BE probabilities.

The informational base includes the formalized descriptions of:

- situations which can arise at PHO;
- situational influences on BE probability.

The description of situations. Each situation is described by a set of causative factors values which influence on a hazard. The factors can be qualitative and quantitative. A qualitative factor is described by a set of its possible values. The quantitative factor is described by the indicating of its minimum and maximum values. Besides, the set of possible values of a factor is divided into ranges. The ranges are established in such manner, that according to expert's standpoint, the influence of a factor on a hazard is constant within each range. As a result, the set of possible values of a factor assumes the form of an expert scale. For each scale, the value of the norm and critical value are established.

Thus, each situation can be described by the vector:

$\left(x_1^0, x_2^0, \ldots, x_k^0\right)$, where x_j^0 - one of possible values of the factor $F_j\left(j = 1,\ldots,k\right)$; K - quantity of the factors which influence on hazard.

All factors used for the description of situations, are independent. The set of each factor values is regulated in such manner that the influence of a factor on technogenic hazard is monotonous.

<u>The description of situational influences on BE probability.</u> The influence function of the factor on BE probability is the accordance between possible values of the factor and BE probabilities, when other factors do not influence on BE origin. Possible values of an influence function of the factor are the BE probabilities. The formation of influence functions can be executed: 1) on the ground of expert estimations; 2) by application of failure models; 3) by complex usage of statistics data and "Analytic Hierarchy Process" method [9]. The influence functions are monotone and can have the tabulated or analytic form.

Let the beginnings of basic event "a" is influenced by the factors $F_j(j=1,...,k)$. At the same time, for each factor the set of possible values X_j and its influence function $f_j(x_j)$ are described (where $x_j \in X_j$). Let values of the factors x_j^t for a current situation are equal x_j^t, i.e. the current situation is described by vector $(x_1^t,...,x_j^t)$.

The estimation problem of simultaneous influencing of the factor's set on BE probability can be formulated as: "To determine the probability BE "a" which arises under simultaneous influencing of the factors F_j when these factors take values x_j^t.

The probability BE can be evaluated according to the expression:

$$P(a)=1-\prod_{j=1}^{K}\left[1-f_j\left(x_j^t\right)\right] \tag{1}$$

Thus, watching for situations at PHO, it is possible to estimate current value of probabilities BE. The outcomes obtained by MEAS can be utilized as input data for traditional PRA methods. The complex of FT, ET and MEAS methods can serve as a modeling-algorithmic basis for systems of the prediction and analysis of technogenic hazard. The information basis (IB) of similar systems is created at a preliminary stage. IB is created with the participation of experts. In further functioning, the IB will be used many times for the assessment of situations without the participation of experts. Let's show calculation of an accident probability estimation in case when it is "Upper" event of FT.

. The calculation of accident probability estimation is executed by application of FT and MEAS methods. FT describes the correlation between resultant ("Upper") event and basic events influencing on it. The basic events in FT are connected by logical elements and are formed in definite parallel or successive combinations. Essential concept is the concept of Prune Cut Set (or simply Cut Set). The Cut Set is a combination of the least number of basic events which can lead to Upper Event. The Upper event can be represented by the disjunction of Cut Sets, that is

$$A=S_1 \cup S_2 \cup ... \cup S_Q \tag{2}$$

$$S_q=a_{q1} \cap a_{q2} ... \cap a_{qL_q} \tag{3}$$

where $q=1,...,Q$;

$a_{ql}(l=1,...,L_q)$ - Basic events that constitute Cut Set S_q;

L_q - quantity of BE in Cut Set S_q.

The probability of the FT Upper Event is determined by expression:

$$P(A)=\sum_{q=1}^{Q}P(S_q) \tag{4}$$

The probability of Cut Set is determined by expression:

$$P(S_q)=\prod_{l=1}^{L_q}P(a_{ql}) \tag{5}$$

Let's substitute (5) in (4) and we'll receive:

$$P(A)=\sum_{q=1}^{Q}\prod_{l=1}^{L_q}P(a_{ql}) \tag{6}$$

The estimation of probability BE a_{ql} can be received from expression (1). For this purpose we shall insert necessary indexes into it:

$$P(a_{ql}) = 1 - \prod_{j \in J_{ql}} \left[1 - f_j^{ql}(x_j)\right] \quad (7),$$

where J_{ql} - set of indexes of those factors which influence on probability a_{ql},

$f_j^{ql}(x_j)$ - value of an influence function of the factor with an index j on BE a_{ql} when the value of the factor is equal x_j.

Having substituted (7) in (6) we'll get:

$$P(A) = \sum_{q=1}^{Q} \prod_{l=1}^{L_q} \left\{1 - \prod_{j \in J_{ql}} \left[1 - f_j^{ql}(x_j)\right]\right\} \quad (8).$$

Conclusion

- The method of formalized description and assessment of situations on potentially hazard objects is offered. The method is named as "Method of Expert Assessing Scales" (MEAS).
- MEAS extends the possibilities of traditional probabilistic safety assessment (PRA).
- MEAS models and estimates technogenic hazard at the stage of its origin, i.e. during latent period.
- The combination of MEAS with traditional PRA methods enables to assess operatively the degree of potential hazard at an object for each situation and to analyze its causes. Thus, MEAS establishes analytical relation between situations at an object and estimations of basic events probabilities. These outcomes can be further used for the calculation of accident probabilities by methods of traditional PRA.
- As a result, a hazard can be assessed at the earliest stage of its development. It enables to arrange the prevention of a hazard in most well-timed phase.
- Thus, the combined application of logical-probabilistic methods and MEAS can be the model-algorithmic basis for information technology of hazard situational analysis and prediction at potentially-hazard objects.

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