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USE OF «TREE OF EVENTS» FOR ANALYSIS OF TRAUMATISM AND ACCIDENTS ON METALLURGICAL PLANTS

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It is executed the analysis of methods for risks existing in industrial safety measureis. There are made examples of the use of construction of «tree of events» and «tree of errors» for the analysis of accidents consequences on a metallurgical plant.

Keywords: industrial safety measures, metallurgy, accident, probability, «tree of events», «tree of errors», analysis

Introduction. In accordance with global strategy of Worldwide organization of poblic health by one of basic directions of development of industrial safety measures avoidance of risks [1,2], and, first of all, prophylaxis of traumas and occupational diseases. The value of methods, allowing beforehand to expect probability of failure or accident in this connection, and also to define the most acceptable and effective ways of decline of this probability increases.

Analysis of achievements. In the sector of industrial safety measures for the analysis of risks expert estimations, economic and ergonometric methods, and also statistical analysis are used.

A security of the difficult systems analysis is executed, as a rule, on the basis of analytic methods with bringing in of the experienced data about refuses and renewal of elements of these systems. By basis of such methods the theory of casual processes (markov, semimarkov and other) serves. So, with use homogeneous markov processes there is described the evolution of the difficult systems with certain limitations, id est. such sizes, as time of faultless work, time of renewal, frequency of refuses, must have exponential distribution and not depend on events preceding [3]. However casual processes in a labor protection far are beyond markov′ processes. An attempt to give up assumption about exponential character of distribution of events results in considerable difficulties from the necessity of drafting of the system of integro-differential equations.

Some authors try to go round the indicated difficulties by introduction of empiric coefficients and additional experienced data. For example, A.G. Popova [4] gives the ground of criterion of risk of injuring in the transport-technological system «operator-machine-environment». In accordance with the offered method for the calculation of risk it is necessary to define the amount of operations for providing of safety of operator taking into quantity its qualification, that for the real system very difficultly, and often and it is quite impossible.

S.V. Gurov [5] offers the system of equations for description of probabilities of readiness and outage (disrepairs) of the technical system. In practice the use of these dependences is very complicated from the necessity of knowledge of characteristics of every element of the difficult technical system.

Methods, based on the construction of the special counts – «trees of refuses, events or making decision» considerably simplify the analysis of random events, including. traumatism and failures. For such analysis knowledge of probability of base events and logic of development of situation is needed. Such methods more than 25 years use in the developed countries for the calculation of risks and making decision in the potentially dangerous systems - AES, aviation, military objectives, metallurgical aggregates [6,7].

Problem formulation. To consider the variants for application of construction methods of «trees of events» for the analysis of traumatism and break down in metallurgy.

Basic part. To define probability of one or another unwanted sequel, for example accident or failure, it is possible by the construction of «tree of failures» (TF) [8], which is a graphic model of various connections of events, resulting to this undesirable event. Refuses can be errors of people, refuse of elements of the systems, intervention from natural forces et cetera. TF helps to find not only probability of undesirable event but also to define minimum sections - the most dangerous chains of events, meaningfulness of separate base (initial) events and, in the total, to work out the most effective measures on the decline of probability of undesirable event. The example of construction of «tree of failures» for the analysis of electric traumatism in metallurgy is considered in work [9].

Other method of analysis of risks is a construction of «tree of events» (TE) - allows to consider logic of development of already being done undesirable initial event (failure, accident, natural calamity, refuse of the system and other) which can happen as a result of this initial event, and named initiator (IE). A method is based on the division of development of consequences of initiator event on a few branching out directions. Consequences IE determined in number on the basis of probability of realization of certain ways of development IE.

TE is logical count, which determines the great number of possible eventual development statuses IE and includes a bubble (actually count-tree) diagram and table, located above it. A bubble diagram is connections of horizontal and vertical lines, going from left to right along the consistently made table elements. In the left extreme table element IE specified, in subsequent are intermediate events. Branching of horizontal line within the limits of some table element is meant either realization (overhead branch) or unrealization (bottom branch) of event, indicated in table element. In right part of diagram at corresponding branches the possible eventual states are specified.

An analysis with use TE is the method of study of chain of events, since first from them, which can lead or not result in fallouts. Thus, a method is especially useful at the study of structure of existing or planned safety (warning, defense, counteraction). For an effective analysis it is necessary correctly to define the first event (IE) which serves as the object of analysis.

There are discriminated functional, phenomenological and combined TE [3]. The first TE examine variants actions of the systems of defense (worked or no), TE second is implementation of functions of safety, third TE, are variants of development of the physical phenomena. Combined TE can examine all transferred variants.

We will consider phenomenological TE for the case of descent of cast-iron cart from rails (fig. 1). In overhead part of table situations which can take place are presented. A count is below situated directly. After every point of branching probability of this way of development events is indicated.

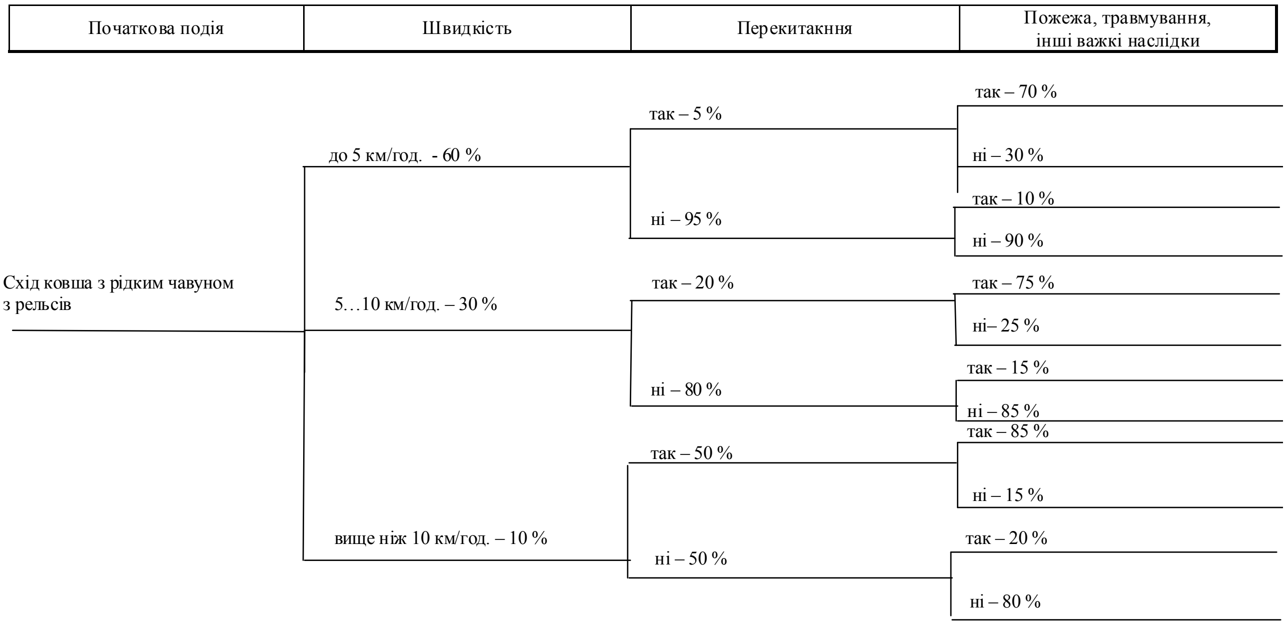

Figure 1 – Tree events for case of descent hot-metal transfercar from reils

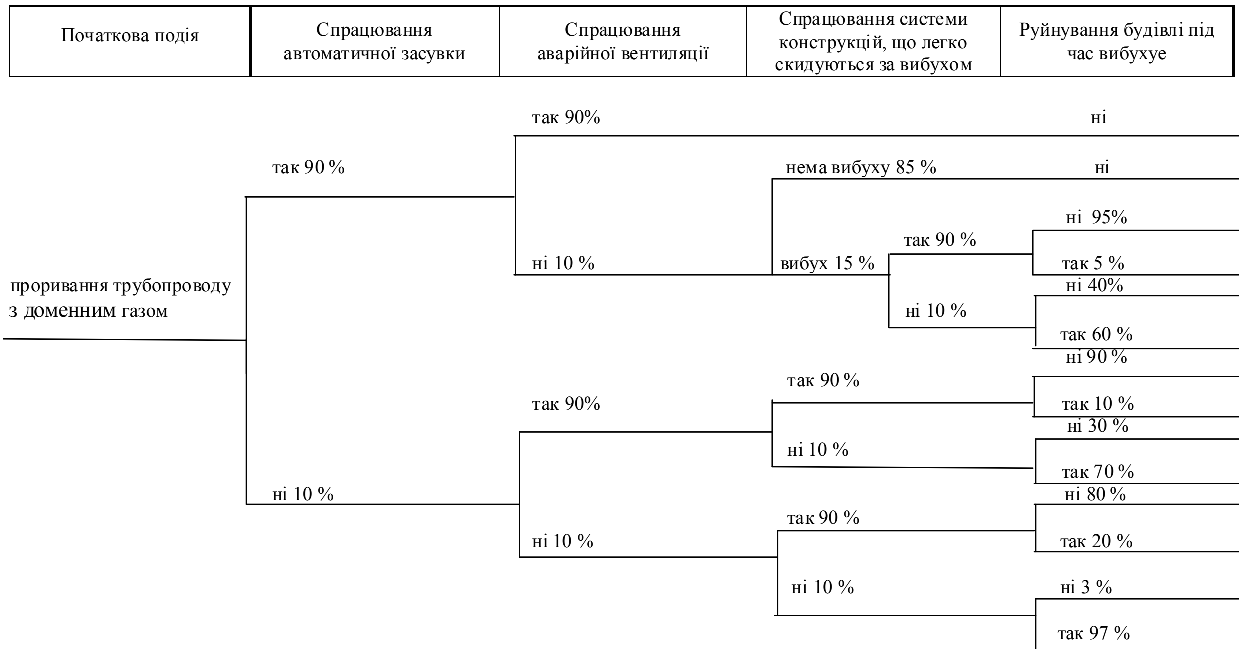

Figure 2 – Outbreak of blast-furnace gas pipe duct in building of gas utilized утилізаційної compressorless turbine

Coming from probabilities of one or another way (which undertake from statistical data or estimate) it is possible to define probability of offensive of heavy sequels of descent of cast-iron cart from the rails of P_m will make:

$$P_П = P_O \cdot P_{TH} + \left(1 - P_O\right) \cdot P'_{TH} \ , \qquad (1)$$

where P_O is probability of diapering of cast-iron cart; P_{TH} is probability of heavy sequel here, P'_{TH} is probability of heavy sequel in case if cast-iron cart does not diapered.

Probability of heavy sequel at speed of cast-iron cart to 5 km/hour make P_{m1} =

0,130, analysing built TE, it is possible to draw conclusion, that probability heavy sequel, at its speed a from 5 to 10 km/hour - P_{m2} = 0.270, at speed a more than 10 km/hour - P_{m3} = 0.525.

Final probability of heavy sequels IE:

$$P_{П} = \sum_{i=1}^{3} P_{vi} \cdot P_{Ti} \ , \tag{2}$$

where P_{vi} is probability of motion of cast-iron cart with certain speed, P_{Ti} is probability of heavy sequels at this speed.

Putting corresponding values in a formula (2) get, P_{mn} = 0,212.

Because the found probability is high, the acceptance of measures is needed for its decline. As such there can be application of cast-iron cart of mix type, having large stability. In addition, even at diapering of ladle, from the narrow mouth of mixer, outpouring of liquid cast-iron will be in less and on less distance, what in the ladle of pear-shaped form.

We will consider system TE for the case of inrush of pipeline of blast gas in building of gas utilization uncompressor turbine – GUUT (fig. 2). Here after every point of branching of event can develop on two variants - the system of defense worked or no. If probability of wearing-out of defense to accept - *P*, then probability of its unwearing-out - (1 - *P*). Probability of successive events is equal product of their probabilities. Probability that one or another will happen from mutually exclusive events equal to the sum of probabilities of these events. On this basis, will expect probability that building of GUUT will not be damaged at the inrush of pipeline:

$$P_{П} = \sum_{i=1}^{n} \prod_{k=1}^{m} P_{ki} = \sum_{i=1}^{n} \left(P_{1i} \cdot P_{2i} \cdot \ldots \cdot P_{mi} \right) \ , \tag{3}$$

where n is probability of one or another event which building of GUUT will not be damaged (in our case n = 8); m is an quantity of events on a way (in our case m = 2.5); P_{ki} is probability of k event on i way.

There are get $P_{П}$ = 0,981.

In an order to get a clear idea, in what direction more effective to work, for increase this probability, probability of wearing-out of three basic protective systems consistently increase on an identical size. At the increase of probability of wearing-out of slide valve from 0.90 to 0.95 general probability of happy end will make: P' = 0.990. Now the same way increase probability of wearing-out of emergency ventilation at unchanging initial probability of wearing-out of bolt : P'' = 0,983. Further increase probability of wearing-out of lightly cropped constructions on the same size at unchanging initial probability of other systems of defense: P''' = 0.985. comparison of values P', P'' and P''' allows to draw conclusion about expedience of increase of efficiency of wearing-out for automatic slide valve.

Analysing the danger of absence of one or another method of defense is possible, by equating to the zero of corresponding probability. In default of automatic slide valve probability that building of GUUT will not be damaged at the breach of pipeline, will make: P_1 = 0,828, in default of emergency ventilation: P_2 = 0,958 and in default of lightly cropped constructions: P_3 = 0,919.

Consequently, absence of automatic slide valve is most dangerous.

The «tree of making decision» or «tree of errors» can be examined as one of varieties of TE. Here the points of branching show development of events on two variants - faithful and erroneous [8]. As an example it is possible to consider the «tree of making decision» at realization of artificial respiration, for example, at a defeat a current (fig. 3).

On a horizontal kind there is put aside correct decisions (small letters), downward for vertical lines - incorrect decisions (capital letters). We designate: *a* - a injured person is placed on a horizontal surface; *b* - a injured person is thrown back a victim and holds out in this position by means of roller under shoulder-blades; *c* - an oral cavity clears up from extraneous objects and mucus; *d* - on a mouth of injured person a serviette or handkerchief is lay down; *e* - the nose of injured person is stopped up; *f* - insufflations of air are done with the required frequency (12-14 time per a minute). Accordingly capital letters mean absence of this action or its wrong feasance. By the dotted line is mark a returnability on a faithful way. If to know a part which is brought by every correct action in general probability of favourable end, it is possible to expect corresponding values for different ways.

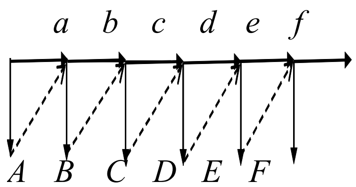

Figure 3 – «Tree of making decision» at realization of artificial respiration

In all different variants of sequences of executions $2^6 = 64$. We accept parts, brought in by different actions in probability of favourable end: $P_a = 0.95$; $P_b = 0.97$; $P_c = 0.95$; $P_d = 1.00$; $P_e = 0.95$; $P_f = 0.90$; $P_A = 0.85$; $P_B = 0.40$; $P_C = 0.90$; $P_D = 1.00$; $P_E = 0.70$; $P_F = 0.20$.

Final probability is equal productrk of corresponding parts. We will present некотрые from results: $P(abcdef) = 0.748$; $P(Abcdef) = 0.670$; $P(aBcdef) = 0.309$; *P*(*авCdef*) = 0.709; $P(abcDef) = 0.748$; $P(abcdEf) = 0.552$; $P(abcdeF) = 0.166$; $P(ABCDEF) = 0.043$; $P(aBCDEF)= 0.048$; $P(AbCDEF) = 0.104$; $P(ABCDEf) = 0.193$.

Most correct way - *abcdef*, most wrong - *ABCDEF*. Probability of favourable end in first case there is more than in the second time in 17.4. The same probability of favourable end as *abcdef* allows to get the way of *abcDef* (the corresponding action *d* is needed for defense of rendering help, but not injured person).

On the basis of analysis of this tree of making decision the most unfavorable variants of combinations of actions (faithful and incorrect) are determined and the methods of their removal are developed. In this case, for example at teaching to realization of artificial respiration are specified at the most dangerous errors (events of *F*, *B*, *E*) their combinations an accent is done on the most essential actions.

Conclusions. Use of methods of construction for «tree of events» and its variety – «tree of making decision», allows to determine probability of one or another way of development of failure, to expose «weak links» in the system of safety, to find the most unfavorable variants of combinations of actions at liquidation of sequels of failure or helping to the injured person.

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