Technogenic risk control

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Abstract The theoretical analysis was carried out on technogenic risk control in relation to one of the elements of a bridge metallurgical crane – its bearing structure, which consists of four sub-elements. Nonlinear dynamics is considered to be the perspective direction in evaluation and control of technogenic risk. The basic application of this theory is described for definite elements of technological equipment technogenic risk control in the metallurgical enterprises. A relatively new theory of channels and jokers is used for description of an object dynamics. There is a need to look for the channels, where it is possible to predict the dynamics of change in the bearing crane structure conditions. The definite algorithm is proposed for the search. The analysis of dependence of channels and jokers and condition dynamics of the bearing structure allows us to operate technogenic risk in terms of algebra logic. The system under discussion with channels and jokers in distinction from standard risks models allows one to take into consideration qualitative (saltatory) transitions.

1. Introduction

There are well known studies of the technogenic risk control at nuclear facilities, rocket and space industry, chemical and oil and gas industry [1-21], but not enough attention is paid to evaluation and technogenic risk control in the enterprises of metallurgical industry. Major technogenic accidents and catastrophes which lead to the environmental pollution, suspension of production and numerous victims are also possible in the metallurgical industry. Besides, at the metallurgical enterprises use so-called the principle of reasonable sufficiency now, that is repair the equipment or replace when it is already really necessary. A large number of the equipment works in the superheavy modes and outside warranty periods. All this affects quality of products and all technological process. The question of management of technogenic risk in this case is certainly relevant.

2. Materials and methods

As risk analysis is related to the effects arising in complicated systems or to the responses to such effects which the complex multi-element system gives, it is possible to use synergetics methods (the theory of joint action) or nonlinear dynamics methods [9,10,13,14,17]. For this purpose the cross-disciplinary approach is used which takes into consideration the emergence of new properties in the complex system which its elements do not have individually.

Nonlinear dynamics can be very useful for evaluation of the personnel opportunities range in the analysis and prevention of technogenic risks. Such analysis relying on computer modeling continuously develops. It is based on the concept of order parameters (the defining role of other

variables and processes). The knowledge of these parameters allows us to identify the main points in the phenomenon and to describe rather simply complex systems in normal and abnormal operating conditions.

The mathematical problems related to the analysis and risk control of accidents and catastrophes are incorrect in the essence. The problem is correct only if its solution exists and this solution is the only possible and stable in relation to parameters.

3. Results

The problems which arise in the risk analysis of metallurgical industry objects are generally incorrect. Cranes, steel ladles, camps and other equipment are made to be in use for rather long period of time. The accidents and catastrophes with metallurgical industry objects constitute a danger and cause serious economic damages [1,2,9,10]. There are obviously not enough publications on technogenic risk control.

By consideration of these facts small indignations which in other cases can be neglected are very essential. For example, the safety of the metallurgical crane in general is defined by a set of minor parameters. Such problems don't seem to fit themselves in the scheme and need new approaches to be invented. Many elements of technological equipment are in use for a long period of time because they have the multiple margin of safety and good operational environment. In modern conditions it is necessary to consider more rigid dynamic, operational, reactionary loadings. In addition, some structures are not produced with enough margin of safety, they can be in use only as long as they are effective.

For risk control $R(t)$ of accidents and catastrophes the tails of distributions related to rare dangerous events at small values $P(t)$ with great damages $U(t)$ have absolute importance [13].

In this regard at present moment the methodology of technogenic risk control develops into two directions:

1) for generalizing of all types of dangerous processes, phenomena and objects;

2) for a definite situation in which the set of essential variables and processes is not really big.

For risk control in space of variables there are areas of high predictability (channels) and areas where the saltatory bifurcation, catastrophic, hardly predictable processes are possible.

The bearing structure condition of the bridge metallurgical crane is characterized by point coordinates $(x_1,\dots,x_4)$ in 4-dimensional space [10], and the future of such system is characterized by its present.

We will consider management of technogenic risk of such difficult technical systems as cranes foundry (mixing, filling, razlivochny) – cranes of bridge type, obrudovanny mechanisms of rise and capsizing of a foundry ladle, intended for pouring and filling of liquid metal. The mechanism of the main rise has two drives connected among themselves kinematic and one drive having ratchet transfers for a possibility of work at an emergency stop of another.

In a design we will consider level: on the first we will divide a design into blocks, local on a mnozhestvka of criteria functions; on the second – we will allocate blocks, local in a set of the varied parameters defining criteria functions.

Subsystem 1 – a bridge metal construction: flying and trailer beams of the main and auxiliary bridges; zones of welding of arms of galleries through passage of the bridge to walls of beams; lower belts of beams;

subsystem 2 – flying beams of the auxiliary bridge: general deformations of beams; local deformations of the lower belts;

subsystem 3 – a traverse of the mechanism of the main rise: hooks; metal construction traverses;

subsystem 4 – ratchet transfer of the mechanism of the main rise: ratchet wheel; doggies; axes of fastening of doggies; clamping springs; axial fastening of a ratchet wheel.

Thus, we have 4 blocks (subsystem) of the first level and ten elements of the second level.

We will consider two extreme cases: summation of damages and multiplication of damages in the course of escalation of damages.

There will be high-risk areas in such phase space. The name of such areas will be "jokers" – rules according to which with some probability $P(t)$ the studied object in phase space can do a jump – to go to some point of the channel or to other joker. The joker can strongly change the chart of bifurcations and hold up the chaos emergence [13].

The joker corresponds to the fact that a number of essential variables changes very quickly, and their quantity can increase. Such variables in the studied object are fatigue of the bearing structure, the saved-up damages (defects), the ultraboundary operating stresses and deformations. Their transition (jump) can result in objectionable risks $R(t) > [R(t)]$. Such account is possible in standard models of risk of the considered designs which can be characteristic of their future states. Dynamic systems with courses and jokers can give an adequate mathematical apparatus for the description and management of technogenic risk.

It is necessary to look for an area where we can predict dynamics of condition change of the bearing structure in the above-stated four parameters - that means to look for a channel. At the present moment such task is intractable, but it is possible to offer the following algorithm, based on [13]:

- to find a projection of small dimension of the orthonormal vectors defining behavior of the bridge crane bearing structure;
- to find area (channel) where the functional dependence between fatigue, accumulated damage, stresses, deformations and the state of the bearing structure will be found by known methods.

In this case it is possible to take a condition of the considered design with acceptable and unacceptable risk level for two courses and also three jokers (is possible more): then the trajectory with some probability gets or to the area of other joker or can go to some point of the course. Such process can be described by means of logic algebra.

Applying this technique, it is possible to calculate levels of technogenic risk for several designs of cranes, shops and production in general, to develop recommendations about further operation of the equipment, having experimental and settlement data between fatigue, the saved-up damages, tension and deformations and a condition of the bearing design.

In this case management of technogenic risk has to be reduced to the following [2]:

- to construction on time of cases of emergence and development of emergency and catastrophic events;
- to assessment of the current values of probabilities and damages to the considered cases taking into account influences and the striking factors;
- to assessment of critical values of parameters of risk on the basis of synthesis of data on a condition of the social and natural and technogenic sphere, on the potential and implemented threats and risks;
- to definition and justification of coefficient of safety on risks;
- to definition and purpose of necessary cost of decrease in risks;
- to justification and choice of a complex of nauno-technical, standard and legal and economic actions for increase in efficiency of decrease in risks.

In the previous works [9, 10] authors have shown that at the considered heavy parameters of operation of metallurgical bridge cranes the probability of emergency situation is in limits 0,400-0,500. Considering that the metallurgical crane consists of a set of responsible elements, the technogenic risk will be estimated as 0,0001 and above. Such data will rather well be agreed with the known data of risks of the metallurgical enterprises and their elements [1]. It means that such approach to management of technogenic risk is lawful.

Such accounting of technogenic risk will allow further his development and accident prevention and accidents and also timely management of industrial safety of difficult technical systems.

4. Conclusion

The analysis of dependence of channels and jokers in a definite situation allows us to determine the level of technogenic risk only in terms of logic algebra.

The system under discussion with channels and jokers opposite to standard risk models allows us to consider qualitative (saltatory) transitions. Such approach to technogenic risk will allow us to operate this risk effectively.

Thus, management of technogenic risk on the basis of nonlinear dynamics finds the increasing application in the theory of safety and risk.

The forecast of such risks has serious uncertainty and is of interest to development as separate branches and to development of all state.

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