Key words: safety, emergencies, terroristic act, explosion, fire, toxic substances, evacuation, automated control

DECREASING SOCIAL AND ECONOMIC CONSEQUENCES OF EMERGENCIES AT RAILWAY TRANSPORT

Summary. The article substantiates the possibility of creating engineering system aimed at automated train control under conditions of emergencies at railway transport. The following emergency reasons are considered: derailment, actuation of explosive devices, spread of toxic substances inside of carriages and driver's inadequate control actions. The criteria of current monitoring of rolling stock movement process along the track are developed. The results of this monitoring are necessary and enough for automated train control under conditions of emergencies. The suggested system is aimed to prevent the emergencies at the railway transport and to decrease social and economic consequences if emergencies occur.

СНИЖЕНИЕ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ ПОСЛЕДСТВИЙ ЧРЕЗВЫЧАЙНЫХ ПРОИСШЕСТВИЙ НА ЖЕЛЕЗНОДОРОЖНОМ ТРАНСПОРТЕ

Аннотация. В статье обосновывается возможность создания технической системы, действие которой, направленно на автоматизированное управление поездом в условиях чрезвычайных происшествий на железнодорожном транспорте. В качестве причин приводящих к чрезвычайным происшествиям рассмотрены: сход колес с рельсов, приведение в действие взрывных устройств, распространение отравляющих веществ в салонах вагонов и неадекватные действия машиниста по управлению поездом. Разработаны критерии текущего мониторинга процесса движения подвижного состава по рельсовому пути, результаты которого необходимы и достаточны для организации автоматизированного управления поездом в условиях чрезвычайного происшествия. Предлагаемая система направлена на предупреждение чрезвычайных происшествий на железнодорожном транспорте, а также снижение социально-экономических последствий при их возникновении.

1. INTRODUCTION

Providing safety of passengers and railway staff and cargo safety is the main task of railway transport. The most dangerous safety risks include derailment, actuation of explosion devices, spread of toxic substances and driver's inadequate actions on train control [4, 7, 18]. Mentioned emergencies may be caused by both random factors and conscious human actions aimed at social and economic damaging that may be classified as terroristic acts [16, 17, 19].

A number of emergencies including terroristic acts at railway transport tends to increase. This is proved by emergencies and terroristic acts happened and carried out at the railway transport and underground in England, Spain, Italy, Russia and other countries [17].

Railway trains operating experience shows that absence of on-time and adequate actions on train control under conditions of emergencies leads to disastrous consequences. Analysis of situation related to the disaster of the German high-speed train ICE on June 3, 1998 near the village of Eschede showed that time of more than three minutes between wheel fracture and train disaster was quite enough for making adequate decisions on train control. But the absence of engineering means for monitoring state of the system “wheel-rail” led to the most disastrous consequences in the history of railways.

Unfortunately the problem of safety of passengers and railway staff and cargo safety under conditions of emergencies is still very urgent and there are no practical results for its solving at railway transport in spite of the conducted researches on this problem [3, 5, 6, 19]. Nowadays modern trains including high-speed ones are not provided with engineering systems aimed at preventing or minimizing social and economic consequences of emergencies and at informing a driver about potential danger. This complicates or makes impossible making right decisions on train control under conditions of emergencies in both manual and automated modes [8, 13, 20].

2. GRAPHIC FORMALIZATION OF DANGEROUS PROCESSES AT THE RAILWAY TRANSPORT

Any extreme situation at the railway transport may be considered as a series of events: technical failure/human mistake/random factor effect – safety risk uprising – absence or disrepair of protective device/wrong human actions for solving problem – impact on people/equipment/environment – social and economic damage [15].

Cause-and-effect graphs in the form of fault tree and events tree are chosen for graphic formalization of dangerous processes at the railway transport. The first graph (fault tree) allows to simulate the conditions of occurring and preventing of unfavorable events and the second one (events tree) – to learn possible outcomes and to analyze the most probable negative consequences. Both graphs are used jointly. [1]

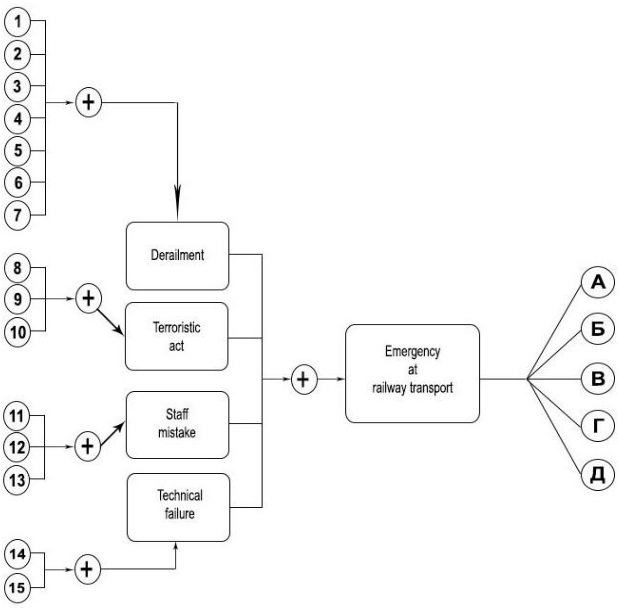

Fig 1. Fault tree (left side) and events tree (right side) for emergency at the railway transport
Рис.1. Дерево чрезвычайных происшествий (слева) и дерево событий – его исходов (справа) на железнодорожном транспорте.

Taken into account presuppositions in the fault tree:
1 – excessive speed;
2 – insufficient speed;
3 – foreign objects at the rails;
4 – bad technical condition of rail track;

5 – bad technical condition of rolling stock;
6 – dynamic state of the system “wheel-rail”;
7 – crashes;
8 – spread of toxic substances inside of the carriage;
9 – explosion inside of the carriages or at the railway track;
10 – fire inside of the carriages;
11 – insufficient skill level of railway staff;
12 – poor physical state of railway staff;
13 – poor psychological state of railway staff;
14 – exploitation expiration of engineering equipment;
15 – design defects.
Possible outcomes in the events tree:
A – impossibility of evacuation;
B – traumatizing of passengers and staff;
C – death of passengers and staff;
D – equipment and environment damage;
E – injury or death of people out of train at the accident scene [4, 7].

3. SYSTEM FOR DECREASING NEGATIVE CONSEQUENCES OF EMERGENCIES

Analysis of research problem and the experience of railways exploitation [3, 4, 7, 13] showed that to organize train control under conditions of emergencies it is enough to monitor the current state of rolling stock movement according to the criteria that characterize safety of passengers and railway staff. These criteria are obtained from the graph:

- derailment;
- activation of the explosive device;
- presence of toxic substances in the air of carriages and space bordering the driver's cab;
- inadequacy of driver’s actions on train control.

Each of these factors and their combination may cause catastrophic consequences for passengers and transport infrastructure on the route.

The results of monitoring of the abovementioned criteria are the information base to develop the algorithms on train control under extreme conditions. Control goals according to the abovementioned criterions are listed in the table 1.

Tab. 1

Control goals by criteria

Criterion	Train control goal according to the monitoring result
Derailment due to the engineering reasons or activating an explosive device.	Automated train stop by a specially developed algorithm which prevents further situation aggravation related to the derailment of other wheel pairs.
Actuation of the explosive device without causing derailment.	Train stop taking into consideration minimization of time spent for rescue works and availability of appropriate territory relief for the stop.

Criterion	Train control goal according to the monitoring result
Spread of toxic substances inside of carriages.	Train stop taking into consideration minimization of time spent for rescue works and availability of appropriate territory relief for the stop.
Driver’s inadequate actions on train control	Automated train stop in the places that provide unhindered access for medical staff and locomotive crew.

As it appears from the table the dominate criterion that requires immediate conversion to the automated train control is derailment. In this case emergency stop is compulsory [14]. But in the case of derailment emergency braking may aggravate the situation and cause further negative development of accidental situation. For this reason braking algorithm must take into account the results of the current monitoring of state of the system “wheel-rail” with the purpose to prevent further derailment and to correct braking parameters in the case of unfavorable development of situation.

Control of the adequacy of driver’s actions on train control is the most complicated task because propriety of taken actions depends on numerous factors. To solve this task one need consider that despite the probabilistic nature of potential mistake it always has reasons and it is based on physiological, psychological and professional components and driver’s experience in working.

In this regard the main method to identify driver’s inadequate actions on train control is comparing current driver’s actions with the test ones that are made on the base of numerous records of driver’s actions at this part of track according with required speed parameters and on condition that there are no infringements on train control.

Such method allows making trip plan-template which is based on the integrated experience of a great number of drivers who have operated trains on this route and haven’t committed infringements on train control. This plan-template defines driver’s necessary actions along the train route with the precise data of where, when and how one need to change parameters of train movement to achieve schedule compliance and compliance with the existing safety requirements.

Deviation of driver’s actions on train control from the test parameters of plan-template will be the criterion of inadequate actions and will be recorded by hardware tools and will be transferred to the main dispatching station on a real-time basis where the final decision on train control will be made.

The combinations of monitoring obtained results are possible according to the suggested criteria. Train control is performed in automated or manual mode in dependence of these combinations. Control efficiency supposes control of devices and systems of rolling stock that are designed for safety maintenance. These systems include:

- braking system;
- sanding system;
- ventilation system;
- fire fighting system.

Obviously, monitoring results of current state of rolling stock movement and listed engineering systems must have function interrelation that provides working modes depending on the monitoring final results. Such functional interrelation is illustrated at fig. 2.

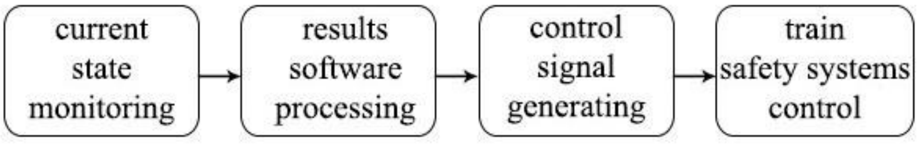

Fig. 2. Structure of train control system under conditions of emergencies.
Рис. 2. Структура системы управления поездом в условиях чрезвычайных ситуаций.

Nowadays there are all technological prerequisites for hardware and software implementation of the suggested system [2, 9, 10, 11, 12, 21] (fig. 2). Table 2 includes the examples of implementation of monitoring of controlled parameters on the base of known physical laws and principles.

Tab. 2

Physical laws and principles for implementation of controlled parameters monitoring

Controlled parameter	Physical laws and principles of control
Derailment	Electrical/capacitive; destruction of sensing element; change of vibration frequency
Explosion inside of a carriage	Atmospheric pressure change
Presence of toxic substances in the air	Analysis of air condition based on the presence of toxic substances
Driver’s inadequate actions	Program analysis of parameters of driver’s actions compared with test plan

Nowadays different areas of industry use sensors operating on the physical laws and principles presented in Table 2 under normal operation and that conduces implementation of the suggested train control system under conditions of emergencies.

Relying on research objective and taking into account the abovementioned, at the fig.3 there is a block diagram of a system of train control under extreme conditions which describes functional cause-and-effect relations between possible risks that predetermine emergency and organizational and control measurements aimed at preventing emergency and decreasing social and economic consequences.

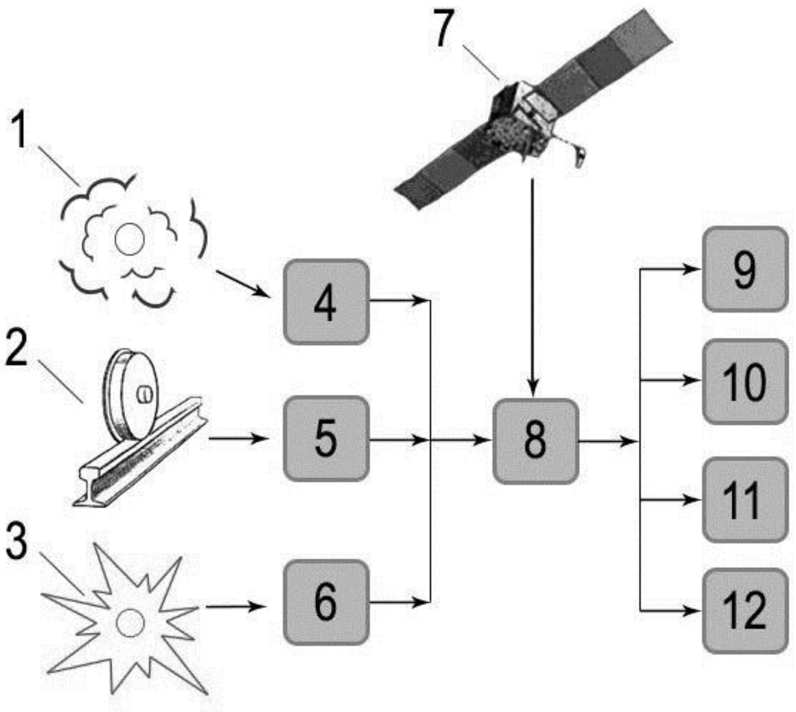

Fig. 3. Block diagram of automated train control system under extreme conditions

Рис. 3. Структурная схема системы автоматизированного управления поездом в условиях чрезвычайных ситуаций.

1 – source of spread of toxic substances; 2 – state of “wheel-rail” system; 3 – source of explosion; 4 – sensor detecting precense of toxic substances in the air; 5 – sensor detecting derailment; 6 – sensor detecting explosion; 7 – Global Positioning System GPS; 8 – onboard computer; 9 – braking system; 10 – sanding system; 11 – ventillation system; 12 – fire fighting system.

Block diagram is a base one and may be added if necessary with new subsystems to provide safety of passengers and railway staff under extreme conditions. Module nature of the suggested system allows adapting it to the existing software of train control.

4. CONCLUSIONS

1. The article substantiates the possibility of creating a system aimed at automated train control under extreme conditions at railway transport. Criteria of current monitoring of rolling stock movement process along the track are developed and results of this monitoring are necessary and enough for automated train control under conditions of emergencies.

2. The results of monitoring of current state of rolling stock movement along the track are the information base for train control under extreme conditions. This monitoring is held by the criteria that characterize occurrence and development of risks for safety of passengers and railway staff:

- derailment;
- activation of the explosive device;
- the presence of toxic substances in the air of carriages and space bordering the driver's cab;
- inadequacy of driver’s actions on train control.

3. The article suggests block diagram of automated train control system in the case of emergencies; system’s functioning is based on the following scheme: “current state monitoring” – “results software processing” – “control signal generating” – “train safety systems control”. The system provides automated train control under extreme conditions according to the specially developed algorithm.

4. Software and hardware implementation of the suggested block diagram of automated system of train control in the case of emergencies will allow increasing the efficiency of train control and providing prevention of emergencies at the railway transport or decreasing social and economic consequences of emergencies if they occur.

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