Failures of safety services in case of emergency fall of cargo-passenger elevator's cabin exploited in industrial and civil premises

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Abstract. The growing fleet of elevators and other short distance vehicles (escalators, passenger conveyors and multi-cabin elevators) require constant improvement of installation methods and technical servicing to increase reliability and safety levels when used. When elevators are used for transporting people, the issue of reliability is becoming very important. The reliability indicator is not a constant value, since it has a direct dependence on a time factor, the main component of which is the standard service life of the main units and kinematic constrains of the equipment used for elevators. As a result, over time, the risk of accidents and emergencies in residential buildings may increase.

1. Introduction
An elevator has become an integral part of the artificially created human environment under technocratic civilization. For almost one century, it was possible to create a fully automated system used for internal transportation of passengers and goods in premises, which functions reliably without requiring special knowledge and preliminary training. The growing needs of social development require constant improvement of internal vehicles used in premises in line with cutting edge technologies. The growing fleet of elevators and other short distance vehicles (escalators, passenger conveyors and multi-cabin elevators) require constant improvement of installation methods and technical servicing to increase reliability and safety levels when used.

Some companies and organizations, which deal with elevator construction, installation and operation, consider as the key to successful solutions the qualified personnel who can keep up with the achievements of science and technology. The urgent need to have the elevator equipment used in premises against the backdrop of a dynamically developing industry was the reason for elevator construction development.

At the end of the 19th century, hoisting winches with a rope pulley were created, in which the lifting force was created due to the frictional interaction of the ropes with the pulley rim. This invention served as a good basis for further improving elevators' design. It became possible to hang a cabin on several parallel branches of the traction ropes, which significantly increased the safety of passenger transportation. The risk of tightening a cabin under the shafts overlap was eliminated, since when the counterweight was mounted on a buffer, the tension of the ropes decreased, and their sliding stopped further cabin's lifting.
The undoubted advantage of using the rope pulleys in the elevator's winches is the independence of their parameters from the vehicle lifting height. This opened up the broad prospects for mass serial production of elevators based on the principles of commoning and standardization of units and parts. The first samples of the rope pulleys had semicircular grooves in a rim, which did not provide the required traction for the ropes and this fact limited the possibility of increasing the lifting capacity of an elevator's cabin.

To compensate for this shortcoming, in 1904, a winch design with a counter-sheave and a double girth of the rope pulley was developed. The double girth of the rope pulley has resulted in reduced rope durability. The solution was found through optimizing the shape of the cross-sectional profile of the grooves of the rope pulley rim providing by this the necessary traction capacity and durability of the ropes.

Further improvement of the elevator design was based on the fundamental decisions discussed above, subsequent achievements of science and industry. The history of the domestic elevator industry development reflected the world trends, although it was happening against the background of the planned economy features and isolation from the external market.

At the end of the 40s, the serial production of general-purpose elevators, special and high-speed elevators was manufactured in our country. In 1955-1956, VNIIPTMASH, together with the SOYUZLIFT Trust, created a standard range of passenger and freight elevators. The systematic development of the domestic elevator industry is associated with the organization in 1963 of the Central Elevator Design Bureau (CEDB) and the further development of the corresponding production base in Moscow and other cities of the country.

The expansion of the production base was accompanied by specialized installation and operation service center for elevators, who was responsible for safety and reliability of the elevators. The companies such as SOYUZLIFTMONTAZH, MOSLIFT and others largely determined the performance quality of the domestic elevators.

Taking into account the foreign experience, in Russia there have been developed the State standards for various types of elevator equipment and architectural and planning solutions applied in constructing premises. Unfortunately, almost complete isolation from the world market and the lack of competition significantly hampered scientific and technological progress in the elevator industry.

Since the 90s, the situation has begun to change. The foreign competitors, when they appeared in the domestic market in the field of production and operation of elevators, have become the incentive to improve the technical level of domestic elevators in extremely unfavorable conditions, when the sharp production fall was in progress in the country.

Currently, there is a constant growth in the elevator fleet with a steady trend towards finding new design solutions that reflect the market requirements and scientific and technological advances in various industries. The organizational forms and technical means of the lift servicing are being improved. Serious attention is paid to increasing the productivity and quality of installation works.

Fierce competition in the domestic and world markets, expanding the range of customer needs in the elevator equipment serve as a good incentive to search for more effective technical solutions.

2. Main trends in elevator construction development

The following main trends in elevator construction development can be noted:

- using new building and finishing materials, including composite materials;
- improvement of cabins' construction and design as well as the equipment used for boarding places, taking into account the factor of anti-vandal resistance;
- design debugging of all systems involved in elevator equipment to reduce the level of noise and vibration in premises and in an elevator cabin;
- expansion of elevators' external installation in recessions of outwalls placed in residential and administrative premises of a tower-based type;
- reliability increase among devices that ensure the safe use of elevators;
- drive systems improvement and expansion of AC drives application with thyristor and amplitude-frequency control;
- control systems improvement based on the achievements of industrial electronics and microprocessor technology;
- use expansion of hydraulic plunger lifts with rope multipliers in low and medium-rise premises;
- comprehensive solution regarding the internal transport used in premises based on combined use of elevators, multi-chamber elevators, and escalators and passenger conveyors;
- extensive use of commoning and standardization methods to improve production quality, reduce the cost of mass production and operating costs;
- practice accumulation on modernization of the elevator equipment;
- service system improvement based on modern methods of computer information processing and control in combination with microprocessor self-diagnosis system for the elevator equipment;
- improvement of elevator design methods based on the widespread use of CAD;
- improvement towards the technology used in the elevator equipment manufacturing based on robotics for production processes;
- efficiency and quality rise towards installation of the elevator equipment based on advanced technology and robotics of labor processes.

To develop the infrastructure of the sectoral economy at industrial and civil construction facilities, the passenger elevators (hereinafter referred to as elevators) have long been used, which ensure people's transportation within the boundaries of the multi-storey space of houses and premises.

Complimented by the increase in multi-storey buildings construction development in cities and regions of our country, since the end of the 20th century, the elevator construction itself began to develop rapidly because the steady demand for the elevator equipment increased. This gave a significant impetus for manufacturers to initiate some improvement regarding the design and production of elevator vehicles. Also, the infrastructure responsible for certification bodies and elevators' control began to develop sharply.

The elevator evolution history says that an elevator was a vehicle that belonged to technical devices used at hazardous industrial facilities. The hazard class to these technical devices was also assigned, in addition, these were facilities under jurisdiction of the Federal Service of ROSTEKHNADZOR (Federal Services for Environmental, Technological and Nuclear Supervision) of the Russian Federation. The hazard category depended mainly on people's movement in a passenger elevator cabin. At present, all responsibility for such vehicles' operation has reduced in certification bodies for technical devices that means the attention to processes and technologies used in production of these lifting vehicles has increased.

As a result, the list of manufactured elevator models has become wider. These models differ in design, security system, location of the main drive elements, automation in control, comfort and ergonomics, as well as, technical operating conditions. When elevators are used for transporting people, the issue of reliability is becoming very important. The reliability indicator is not a constant value, since it has a direct dependence on a time factor, the main component of which is the standard service life of the main units and kinematic constrains of the equipment used for elevators. As a result, over time, the risk of accidents and emergencies in residential buildings may increase. When such situations have emerged, they are impossible without human casualties, because people are the main users of passenger elevators.

The safety operation and reliability of the elevator in emergency situations, when cable binders have broken for the emergency braking, can be provided by the special constructions, called elevator catchers. Herewith, there is a certain risk of causing serious and bodily harm to people who are at that moment in a passenger cabin. As proof for it, there is a significant amount of information in mass media of the Russian Federation, as well as outside our country, on emergencies and their consequences.

According to the Committee on Analytics and Statistics (ELIAS) of the National Elevator Union, today in Russia there are about 530,000 elevators in apartment buildings, 150,000 of which have already worked their life cycle, which is 25 years. In other words, every third elevator needs to be replaced.
During this year about 25,000 elevators in new buildings have been put into operation in our country, and only 9518 elevators have been replaced, which is 2.2% of the required number. In 2020-2021, it is planned to replace about 5,000 old elevators, whereas 10,000 elevators are improving their resources every year. This means that the rate of equipment ageing, according to experts, will increase. The technical condition of elevator equipment in Russia shows off, for last 5 years, the dynamics of fatal injuries due to not safety work of elevators:

- in 2014 - 12 people were killed;
- in 2015 - 12 people were killed;
- in 2016 - 21 people were killed;
- in 2017 - 35 people were killed;
- in 2018 - 29 people were killed;
- in 2019 - 32 people were killed.

These are officially recorded figures registered with the Federal Service of ROSTECHNADZOR. There are also unaccounted accidents that occurred when people moved in elevators. The reliability level decreases due to various factors: electrical, mechanical, physical, metrological and many others. This leads to necessity to carry out more detailed repair of the main elements of elevator equipment with documentary evidence and major repair of the hinged elevators. All these necessities are incentives to search for reliable safety constructions that will ensure for people a comfortable movement between floors.

References

[1] *Rules for the construction and safe operation of elevators*. PB 10-558-03
[2] Ioffe E Ya and Glunov V R 1994 *Elevator certification* (Moscow: Stroyizdat)
[3] Volkova D P 1999 *Elevators. Textbook for universities* (Moscow: ASV Publishing house)
[4] GOST R 53781-2010 *Elevators. Rules and methods of research (testing) and measurements for certification of elevators. Sampling rules* (M.: Standartinform, 2010)