Ensuring the safety of lifts in operation

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Abstract. The article discusses the issues of improving the safety of automobile lifts during operation. A safety assessment is proposed to be carried out using complex reliability indicators that include the loss coefficient. After conducting a cluster analysis of a car lift, the authors determined the failure rates and recovery time for each element. The paper determines the dependence of the recovery intensity on the waiting time as well. In accordance with the contribution of each element, there article calculates the safety level of the lift. Taking into account the statistical data, we determine the contribution of each element of the elevator to risk-safety, which corresponds to the percentage of output applications of the lift’s individual elements. According to the obtained dependences, the safety level of the elevator is determined from the lift’s service time. The proposed technique will allow determining the safety level of the lift during certain periods of service to reduce downtime and increase the efficiency of use.

1. Introduction

Nowadays in construction and other works at height, lifts are used when it is necessary to transport goods and deliver people. Their functional purpose is not limited to the construction site, they are used for storage, repair and redevelopment.

Safety of the lifts is estimated by the criticality of events that are set for each specific case on the basis of expert analysis. For systems with a high degree of risk and complexity it is recommended to use a probabilistic risk analysis [1-12]. Safety assessment can be done by using complex reliability properties (reliability, durability and maintainability), quantitatively represented by formulas, including the loss factor as an indicator of a separate property [13].

\[
K_j = \frac{1}{1 + \frac{T_{su}}{T_{sap}}},
\]

(1)

where \( T_{su} \) -recovery time of \( i \)-th element;

\( T_{sap} \) - time between failures.

Lifts are complex technical systems, so the danger during operation can arise in the form of failure of their structural elements. The main causes of failures of lifts are: design flaws, the quality of the
elements manufacture, and the low level of their maintenance. Ensuring the safety of the lifts operation with the adjustment of the resource components for a certain period of service is an important task.

In order to solve this problem, it is necessary to analyze the faults and identify the elements with “weak” reliability. Then it is possible to work out the proposals for improving the safety level of the lifts on this basis.

2. The main part

Improving the level of safety requires addressing the issue of raising the technical level of the lifts manufacturing, the quality of their maintenance and repair. In addition, it is necessary to use the lift to its intended purpose, and to carry out maintenance and diagnostics in a timely manner. Analysis of various structures of automobile lifts showed that they are equipped with the following safety elements: critical load limiter; gravitational locking system of rotation and boom lift with non-exposed supports; a device for blocking the lifting of supports with the working equipment raised; a device protecting the outriggers from spontaneous extension when working with the cradle; system of an emergency stop of movement when controlling from a working platform. During operation, this equipment requires careful maintenance, monitoring and high-quality diagnosis. These measures make it possible to promptly determine the causes of faults in the lifts, which helps to reduce downtime and operating costs. Creating a diagnostics system for lifts can significantly reduce downtime for technical reasons and speed up troubleshooting. [14,15]

Safety is the absence of unacceptable risk, where the required level is achieved by specialists with a certain recovery rate. Solving such problems rationally, we propose to use the method of hierarchical clustering, which can clearly provide a solution with the construction of a tree diagram-dendogram.

In addition, the method of clustering elements of lifts allows us to gather the nodes into clusters for functional purposes. On the basis of statistical data on the operation of automobile hydraulic lifts that worked at various sites in Moscow, the following elements were established from the position of reliability: internal combustion engine (ICE), hydraulic system, running gear.

Automobile hydraulic lift is a special type of equipment that is widely used in construction, therefore, the safety of operation and service life are important factors. The elements of general functionality in automotive hydraulic lifts are: internal combustion engines, clutch, starter, cooling system, valve, hydraulic motor, hydraulic cylinder, highway, pump. Let’s consider the dependence of the intensity of recovery (repair) of lifts $\mu$ on the waiting time before troubleshooting $T_{\text{ox}}$. The results of the analysis of some elements of the lifts are presented in Table 1.
Table 1. Summary statistical data on the recovery of the elements of automotive hydraulic lifts for one year.

| Recovering element | Number of applications, (count) | Recovery time, (hrs) |
|--------------------|---------------------------------|----------------------|
| ICE                |                                 |                      |
| Clutch             | 4                               | 28,3                 |
| Starter            | 2                               | 3,1                  |
| Internal combustion engine | 7                      | 22,8                 |
| Carburetor         | 1                               | 4                    |
| Cooling system     | 1                               | 25                   |
| Hydraulic motor    | 4                               | 148                  |
| Track              | 6                               | 230                  |
| Control valve      | 2                               | 158                  |
| Valve              | 2                               | 108                  |
| Pump               | 1                               | 99                   |
| Hydraulic motor    | 1                               | 168                  |
| Muffler            | 1                               | 8,4                  |
| Springs            | 1                               | 67                   |
| Tyre covers        | 1                               | 5,5                  |
| Rear bumper        | 1                               | 9                    |
| Tank leakage       | 1                               | 3,87                 |
| Wing welding       | 1                               | 4,1                  |

According to the data of the table, the dependence of the recovery intensity of the lifts on the waiting time for recovery (repair) is constructed (Figure 1) with least squares approximation:

$$\mu = 2,601 T_{ож}^{-0.322},$$

(2)

Figure 1. Dependence of the recovery intensity of the lifts $\mu$ on the waiting time for recovery (repair) $T_{ож}$.

According to the operational data, the automobile hydraulic lift works in 1.5 shift mode at a construction site for a year. According to the passport of this lift, the service life is 20 years, then the number of working hours for the entire service life will be 46 thousand hours.
Taking into account these sources, the failure rate of a hydraulic lift for one year is determined by the formula [16]:

\[ \lambda = \frac{m(\Delta t)}{N \cdot \Delta t}, \]  

(3)

where \( \lambda \) - intensity of the lift failures;

\( m(\Delta t) \) - number of failures;

\( N \) - number of elements failed during the period \( \Delta t \).

Taking into account the statistical data, we determine the contribution \( b_i \) of each element of the elevator to risk-safety, which corresponds to the percentage of output applications of the lift’s individual elements. The rank of repair costs is determined by the dependence [17]:

\[ r_i = \frac{T_{oai} + T_{pi}}{\sum_i (T_{oai} + T_{p})}, \]  

(4)

where \( T_{oai} \) - waiting time before eliminating the continuity of the \( i \)-th element;

\( T_{pi} \) - recovery time of the \( i \)-th element;

\( T_{oai} \) - total waiting time for all items.

We can estimate the danger risk with the formula:

\[ P_i = b_i \cdot r_i. \]  

(5)

The safety level of one lift operation, taking into account the contribution to it of elements, is estimated by the formula:

\[ E = \sum (1 - P_i) = 0.821. \]  

(6)

For the elements of the lift (table), the failure rate (\( \lambda \)) is determined by the formula (2): for the internal combustion engine - \( 3.76 \cdot 10^{-4} \); hydraulic system - \( 3.52 \cdot 10^{-4} \); the chassis - \( 3.25 \cdot 10^{-4} \), and the recovery rate (\( \mu \)) is determined by the formula [17]:

\[ \mu = \frac{1}{T_{oai} + T_{pem}}. \]  

(7)

Where \( T_{pem} \) - time of the element’s recovery.

According to the formula (6), for ICE - \( \mu = 0.052 \), hydraulic system - 0.017; chassis - 0.036.

Fig. 2 shows the dependences of the ratio of the failure rate (\( \lambda \)) to the recovery rate (\( \mu \)) on the number of applications (\( K_x \)) for repairs for ICE - 1, the hydraulic system - 2 and the chassis - 3, where

\[ \Psi = \frac{\lambda}{\mu} \]  

is the ratio of the failure rate to the recovery rate.

Based on the obtained dependencies, we determine the safety level of the lift from the service life. Data on the operation of automotive hydraulic lifts at different sites allows us to establish the dependence of the number of failures of individual elements of the lifts (\( K_{oi} \)) on the service life (\( T \)), the equations of the approximating curves, which look like:

For ICE - \( K_{oi} = 0.71T^2 - 5.1T + 16 \); hydraulic system - \( K_{oi} = 0.63T^2 - 4.2T + 8.5 \) and chassis - \( K_{oi} = 0.58T^2 - 5.71T + 12.1 \).
Figure 2. Dependences of the ratio of the failure rate ($\lambda$) to the recovery rate ($\mu$) on the number of applications ($K_z$) for repairs for ICE - 1, the hydraulic system - 2 and the chassis – 3.

Considering the average service life of internal combustion engines, hydraulic systems and chassis, we can determine the number of failures for different service lives, which makes it possible to rationally carry out restoration work and systematize the maintenance and diagnostics. This approach allows us to assess the level of safety of lifts at various points in operation and to identify the qualitative and quantitative indicators of the level of safety.

3. Conclusion

The proposed method for assessing the level of safety of automotive lifts can reduce downtime and increase their efficiency.

Moreover, it can help to plan the diagnosis of the main elements of the machine and prepare a stock of sets of equipment for the repair and replacement of failed elements.

References

[1] Ancev V Yu , Tolokonnikov A S , Gorynin A D 2013 Automation of the failure risk estimation of cargo cranes // Izvestiya TulGU Technical science 7(1) 214-20
[2] Zorin V A 2005 Performance bases of the engineering systems: the textbook for high schools M : OOO Magister-Press, 536
[3] Zorin V A, Dauhello V A , Sevryugina N S 2009 Safety requirements for the land transportation systems: a textbook Belgorod: BelGTU, 186
[4] Polyakov Yu I 2008 Theory of danger manifestations: the main strategy tasks of the engineering safety regulation by technical standards // Bulletin of the Scientific Center 2 154 – 64
[5] Sevryugina N S 2012 Theory of technical safety formation of the complete transport and technological machines life cycle: monograph Belgorod: Publishing house of BGTU 179
[6] Sevryugina N S , Stepanov M A , Mechiev A V 2017 General methodological approach to the risk assessment of the structural safety of elevators // Mechanization of construction 78(4) 24-9
[7] Stepanov M A , Mechiev A V 2016 Modeling of the elevator park maintenance system // Scientific Review 3 27-32
[8] Telichenko V I , Zavalishin S I , Khlystunov M S 2005 Global risks and new safety hazards of the important construction sites of the megalopolis // Book of reports of the thematic scientific and practical conference “City construction complex and the safety of citizens” - Moscow: MGSU, 211-8
[9] Baurova N I, Zorin V A, Prikhodko V M 2015 Description of scenarios of transition of material from an operable to inoperable state using an equation of fold catastrophe theory Polymer Science Series D 8(1) 1-5

[10] Baurova N I, Zorin V A, Prikhod'ko V M 2015 Influence of structural defects in carbon fibers on their sensor properties evaluated using scanning electron microscopy Fibre Chemistry 46(5) 283-7

[11] Baurova N I, Zorin V A, Prikhodko V M 2015 Description of scenarios of transition of material from an operable to an inoperable state Polymer Science Series D 8(1) 1-5

[12] kov A A, Roytman V M, Shilova L A 2016 Model of stability of life support systems in emergency situations International Journal of Applied Engineering Research 11(3) 1666-9

[13] Sevryugina N S, Stepnov M A Vertical transport: resource by the criterion of safety Vertikalny transport: korrektirovka resursa po kriteriyu bezopasnosti» Inzhenerno-stroitelnyy zhurnal 72017 23-35 doi: 10 18720/MCE 75 3

[14] Rashid Sharapov, Vitaly Vasiliev 2017 Analysis of the spectrum distribution of oscillation amplitudes of the concrete mix at shock vibration molding MATEC Web of Conferences 117 (2017) RSP 2017 – XXVI R-S-P Seminar 2017 Theoretical Foundation of Civil Engineering, Warsaw, Poland, August 21-5

[15] Plavelsky E P, Sharapov R R 2017 The Problems of Dynamics of Wheeled Vehicles with Flow Able Building Cargo International Conference on Industrial Engineering, ICIE 206 86-92

[16] Stepanov M A, Kvatukov B A, Releabity and Safaty of Transporntation of Use IPICSE-2018 https/org 10 1051201875 103 013

[17] Stepanov M A, Kvatukov B A, Mechiev A V Opredelenie urovnya bezopasnosti liftov pri ekspluatatsii Podemno-transportnoe delo 6(1018) 7-10