Details of Inspection of Static Ropes with Polyester Sheath after Contact with Various Acids

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Abstract. This article considers static ropes - one of the components of a personal fall protection system when working at heights. The issue of accidents when working at heights in Russia and abroad is raised. The inspection of the ropes is considered as one of the local mechanisms to reduce injuries when performing work at heights, as well as the advanced training of specialists responsible for the inspection of personal protective equipment against falling from a height. The effect of acid solutions most commonly encountered in industrial activities with short-term contact and with prolonged contact on polyamide ropes is investigated. Recommendations are given for a more competent use of these products in various situations without compromising safety. The questions of solving the problem of the hidden effect of acids on static ropes with a polyester sheath are raised.

1. Introduction

One of the components of personal fall protection systems for working at height is a static rope (hereinafter rope). The first personal fall protection system that uses ropes is the rope access [1] (hereinafter RA). RA is widely used in industrial facilities of the oil and gas sector, in the maintenance of facades of buildings and structures in the urban environment, where the use of small-scale mechanization is economically inferior to the above-mentioned security systems (figure 1). RA usually uses two lifelines: a working line and a safety line. A working line takes a static load during operation, the safety line takes a dynamic load during failure. The length of the ropes used for work in RA can be several hundred meters on high buildings and structures, and the total length of all the ropes in one fall protection systems can reach up to one km (figure 2).

The second most common use of ropes as a component of a fall protection system is a flexible lifeline systems [2-4] (hereinafter FLS), along which a guided type fall arrester moves, which stops the user from falling in the event of a break. In some cases, a retractable type fall arrester is connected to the horizontal lifeline [5], and in this case the user's fall is stopped by this device in conjunction with the lifeline. In this case, FLS consists entirely of a rope and is a safety line, and the working line in the case of using these systems are structures on which the user moves connected by a sling with a shock absorber [6, 7] and a guided type fall arrester to lifeline. These lines can be used both in vertical design, for example, stretched along a vertical ladder, and in horizontal design, installed, for example, on the roof of a building. Horizontal solutions are part of the restraint system and do not allow the user to get into an area with a possible risk of falling from a height, while allowing you to move freely along it to perform work tasks.
The third direction of using ropes in fall protection systems can be considered slings for restraint and work positioning [8]. These products in combination with other system components (such as harnesses for restraint and work positioning) allow the user to work with an emphasis on structural elements or is suspended in the work area. All three systems using rope as a component of fall protection systems are widely used to ensure the safety of work at height.

2. Relevance
Annual reports of statistics on labor protection show that in Russia the number of accidents during work at height is in the first place. This type of injury occupies an average of 30% of all severe and "lethal" statistics, of which more than 35% are fatal. Around the world, this problem is also in the first place in the number of injuries [9-15]. Issues of ensuring the safety of work at height are an urgent problem and require local study on various aspects and directions of safety.

3. Setting of the problem
The object of study of this paper is rope as a component of fall protection systems. Researches of ropes for sports and accidents in sports can be found in [16-19]. Today, industrial ropes are manufactured for Russia in accordance with GOST EN 1891. These ropes are made of synthetic fiber with a melting point of more than 195°C, structurally made of a core and sheath. The core is the inner part of the rope, consisting of synthetic threads that form several twisted veins, the main function of which is to accept the load when using the rope both under static and dynamic loadings. The sheath is the outer part of the rope, which is a cylindrical frame made of synthetic threads, one of the functions of which is to protect the core from external factors. The most common materials used for making ropes according to GOST EN 1891 are polyamide (PA) and polyester (PE). The primary characteristics of PA fibers are: high strength, relatively light weight. Disadvantages, in turn, can be identified as weak resistance to acids and changes in the properties of fibers when moisture is absorbed. Advantages of PE fibers in relation to PA fibers: higher wear resistance, less reaction to acids and higher resistance to temperature. Disadvantages include greater weight. Therefore, the combination of a PE sheath and a PA core is a good mutually beneficial synthesis of the characteristics of these fibers.

One of the local actions to improve the level of safety of work at height is to increase the culture [14, 20, 21], the competence of specialists and the mechanisms of inspection control of personal protect equipment (hereinafter PPE) [22]. As part of the activities of training centers, as well as
independent educational courses, training is conducted on detailed inspections of PPE by a competent person.

Loss of strength, as well as contact with any chemical substances, is a mandatory criterion for the rejection of any PPE, including ropes. The question arises in determining the visual and tactile criteria for which these PPE will be removed from the workflow. Peak loads in RA can reach 150,7..544,9% of the load created by the weight of the user under various circumstances [23]. The percentage of rope strength loss due to wear reaches up to 37%. The combination of even above three criteria can lead to the destruction of the safety system in the normal operating range of loads.

The purpose of this work is to determine the residual strength, as well as visual and tactile criteria after exposure of various acids on samples of PA ropes, including those with PE sheath.

4. The research method
The acids most frequently encountered in production activities were selected for testing:

- sulfuric acid H₂SO₄ in concentrations of 45% and 20% (found in car batteries, in the detergent ATS-350);
- hydrochloric acid HCl in concentrations of 15%, 10% and 5% (found in the composition of all flushing effluents from walls, in the detergent ATS-350);
- phosphoric acid H₃PO₄ at a concentration of 30% (found in rust converters).

The time of acid exposure to the samples at this stage was 30 seconds and 1 hour. The exposure time of 30 seconds was taken as an imitation of an accidental acid drop on the rope, and the exposure time of 1 hour is a conditional time during which the rope can be under the influence of substances during the work. After exposure to acid, the samples were kept for 5 days in a room at a temperature of (22 ± 3)°C and humidity 44..53%. Then the samples were tested for static strength in accordance with the established procedure on test stands [24], the results were compared with the strength values of the control samples.

5. Results of experiments
Figure 3 shows a summary of the residual strength of the test samples. The diagram shows that the loss of strength in most cases is critical. As a result of even short-term exposure, within 30 seconds, the loss of strength was from 16,7% to 53,1%.

![Figure 3](image-url)

The acid, concentration, time of exposure

**Figure 3.** Summary of the residual strength of the PA ropes after exposure to various acids.
In this work, the visual state of the ropes after conditioning for 5 days is of particular interest. Figure 4 shows the condition of samples with sheath made of two different materials, with a loss of strength of almost 80%. The PE sheath sample lost 62.5% in strength, while its visual state does not reflect significant acid exposure, unlike the PA sheath sample.

![Image 1](image1.png) ![Image 2](image2.png)

(a) Sample with PA sheath; residual strength 20.7%  
(b) sample with PE sheath; residual strength 37.5%

**Figure 4.** The state of the sample’s sheath after exposure to H\textsubscript{2}SO\textsubscript{4} with a concentration of 45% for 1 hour and subsequent conditioning for 5 days under normal climatic conditions.

Special attention should be paid to the fact that when exposed to H\textsubscript{2}SO\textsubscript{4} at a concentration of 45% for 30 seconds, the sample with PE sheath had almost no visual and tactile changes in contrast to the new one, while the percentage of residual strength was 46.8% (figure 5).

![Image 3](image3.png) ![Image 4](image4.png)

(a) Sample with PA sheath; residual strength 54.6%  
(b) sample with PE sheath; residual strength 46.8%

**Figure 5.** the state of the sample braiding after exposure to H\textsubscript{2}SO\textsubscript{4} with a concentration of 45% for 30 seconds and subsequent conditioning for 5 days under normal climatic conditions.

6. Suggestions
One of the way for improving safety in the situation described above can be the introduction of pigments in the PE sheath, which, when in contact with acids, will reveal the very fact of exposure in the form of visual and tactile criteria. If there is such a solution, a further step can be the introduction of chemical inertia testing in national standards in the form of quality criteria. If this approach is successfully implemented, this technical requirement can be implemented as a safety criterion.

7. Conclusions
According to the results of the study, it is clear that the use of synthetic ropes next to various chemicals can carry a hidden threat. Specialists responsible for organizing work at height should take into account when planning work that in case of any possible contact with chemicals, even in an indirect way, it is better to refuse to use ropes of this design. This work does not aim to discredit this constructive solution, but focuses on more competent use of PPE in various situations without compromising safety.
8. References

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