

Analysis of the processes occurring in textile PPE against falls from a height under weather conditions

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Abstract. The construction site is the leader in the number of injuries, among which a significant proportion are falls from a height. When carrying out work at height, PPE (personal protection equipment) and CPE (collective protection equipment) are used, which can be made of metal or synthetic polymers. Unlike metals, synthetic polymers are less resistant to processes occurring when working in atmospheric conditions. The aim of the work is to increase the safety of PPE users and attract more people related to occupational safety to the problem. In the course of the work, articles containing information about the processes occurring in polymer synthetic materials were analyzed. Data were obtained on the relationship of these processes to each other and their combined effect on the rate of change in the chemical composition of the material. In the end, conclusions were drawn about the deterioration of the physico-chemical properties of materials after exposure to weathering condition.

Key words: labor protection, occupational safety, PPE against falls from a height, work at height, weathering, UV-irradiation, hydrolysis, glass transition, autoxidation, photodegradation

1. Introduction

Construction is the largest sector of the Russian economy in terms of the number of investments and the number of employees. To date, according to the Ministry of Labor and Social Protection of the Russian Federation, six and a half million people are employed in the construction industry [1]. The construction site is the leader in the number of injuries suffered by workers, a considerable proportion of which are falls of the victim from a height, including a fall on a flat surface of one level [2]. To prevent occupational injuries, the Ministry of Labor of the Russian Federation takes a set of various measures, including the requirement from employers to provide workers with mandatory means of protection from falling from a height [3].

There are collective and personal equipment of protection against falling from a height, which today are represented by a large number of different types of products, this allows employers to choose the equipment of protection based on the type of work, the situation on the construction site etc. In the production of CPE and PPE from falling from a height, materials such as:

- Metals and their alloys (manufacture of connectors, rigid anchor lines, cables, etc.);
- Synthetic polymers (manufacture of lanyard [4], energy absorbers [5], harnesses [6], protective trapping nets, etc.)

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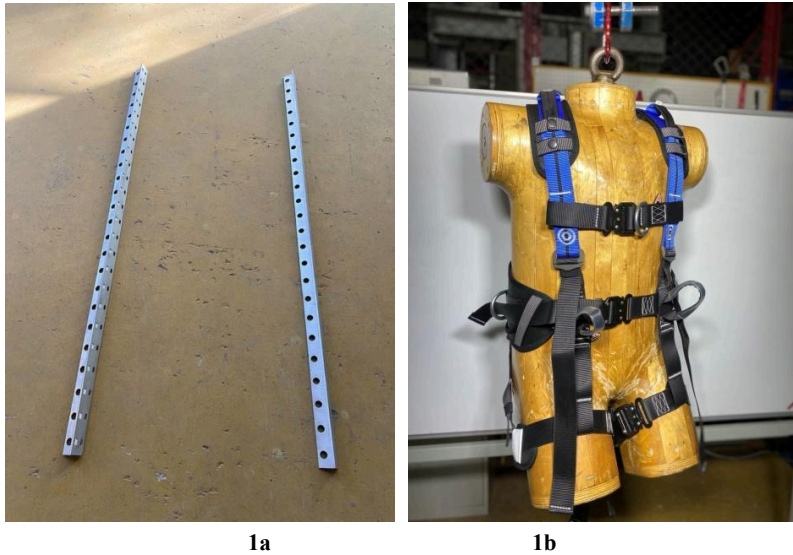


Figure 1. 1a - an example of a guide rigid anchor line made of steel; 1b – an example of a harness made of polyester

Due to their crystal lattice, metals are more durable and durable compared to polymers – macromolecules consisting of a chain of monomers. Unlike metals and alloys, synthetic polymers are an amorphous materials with a fairly low melting point and higher plasticity.

When working at height on a construction site, a factor that has a negative impact on PPE and CPE from falling from a height is weather conditions. Weather conditions is the combined effect of air humidity, ambient temperature, and sunlight. The negative effects of weather conditions during work in atmospheric conditions are much more susceptible to PPE and CPE made of polymer materials, which have a low melting point, are subject to photooxidation, a decrease in the glass transition temperature when saturated with water, and loss of strength due to glass transition.

The main processes of degradation of polymer materials under the influence of weather conditions are hydrolysis [7], autoxidation (photooxidation) [8], glass transition.

Aim: improving worker safety when performing construction work at altitude in weather conditions; attracting more people related to the field of occupational safety to the problem of the influence of weather condition on PPE against falls from a height.

Objectives:

- To analyze scientific works devoted to the consideration of chemical processes occurring in synthetic textile materials when working at height;
- Identify the main processes, consider their effect on the material and the relationship between them, as well as changes in physico-chemical properties;
- To draw a conclusion about the influence of chemical processes on the safety of the user when performing construction work at height.

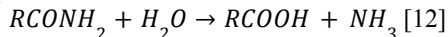
2. Analysis

2.1 Hydrolysis

The absorption of water by polymer materials can cause their swelling, accompanied by an increase in mass, volume, and a change in structure [9]. Water is an environment that is chemically aggressive to polymers that contain easily hydrolyzable bonds. The decrease in the chemical resistance of the chain is caused by the presence of nitrogen, hydrogen and silicon atoms, as the authors [10] write in detail. Atoms of these elements are contained in chains of

nylon 6 monomers (a family of synthetic polyamides), polyester is the most widely used in the production of textile PPE and CPE from falling from a height.

Considering the hydrolysis of nylon 6 in more detail. It is also known as nylon or polyamide 6 (PA6) [11] – a synthetic fiber containing special amide groups that undergo hydrolysis, their reaction proceeds as follows:



Which in turn negatively affects the physico-mechanical and chemical properties, such as:

- weight loss;
- reducing the length of the chain;
- reducing the glass transition temperature.

The authors [13] obtained data that as nylon 6 is saturated with water, the glass transition temperature decreases, with full saturation with water, its mass fraction reaches 9%, and the glass transition temperature decreased from 66 °C in dry conditions to -9 °C.

2.2 Glass transition

The glass transition of polymers is called the change in the structure of a material from an elastic state to a solid, glassy state. Having been subjected to glass transitions the polymer changes its mechanical properties, loses plasticity and becomes hard and brittle. The glass transition temperature varies for different polymers (see Table 1) some materials are used at temperatures significantly lower or higher than that at which the transition to a glassy state takes place.

Table 1. The glass transition temperature of polymers used in PPE against falls from a height

Polymers	The glass transition temperature
Polyamide 6	50 °C
Aramide	370 °C
Polypropylene	-10 °C
Polyester	81 °C

2.3 Autoxidation

All organic polymers are prone to autoxidation [14] – reactions of interaction with oxygen, in which light, in particular UV radiation, is the catalyst [15]. Autoxidation is a complex reaction during which new products are created that can independently react with polymer molecules. Thus, according to the study [16] of the photochemical effect of photoinitiated oxidation (photooxidation) of polymers with an increase in the dose of absorbed light (Fig. 3), the amount of autoxidation products formed increases.

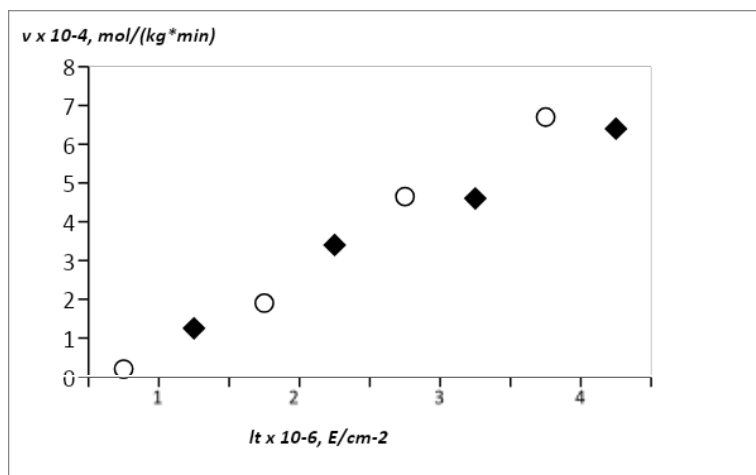
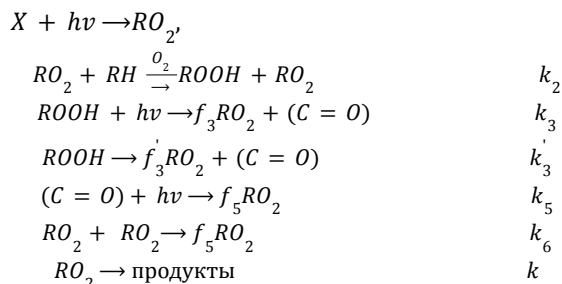


Figure 3. Dependence of the rate of photooxidation on the dose of absorbed light [16]. ○ – the first sample containing 0.095 mol/kg of diphenylethanedione; ◆ – the second sample containing 0.095 mol/kg of diphenylethanedione

The scheme of photooxidation using the example of polypropylene is presented by the authors [17]:



where X is the photoinitiator, $RO_2 \cdot$ – polymer peroxide radicals RH, ROOH – hydroperoxide, (C = O) – carbonyl compounds, $k, k_2 - k_6$ – constants of reaction rates, f_3, f_3', f_5 – probabilities of radical escape from the cell in the corresponding reactions

By conducting exposure to accelerated weather conditions of another commonly used polymer in the production of PPE against falls from a height - polyamide 6-6, the authors [18] received information that short-wave UV radiation in combination with oxygen, temperature, moisture causes serious changes in the surface layer, but at the same time, the authors believe that photochemical reactions have the greatest effect on the change of the material.

3. Conclusion

In the course of the work, an analysis of the processes occurring in textile PPE from falling from a height during construction work in atmospheric conditions was carried out. The authors of the above studies conclude that the processes occurring under the influence of weather conditions on the PPE material lead to a deterioration in the properties of products. It was also reported that the processes, namely hydrolysis, glass transition and photooxidation, are closely related to each other, affecting the reaction rates.

The author consider it necessary to pay closer attention to the problem of the impact of weather conditions on PPE from falling from a height, which has a direct impact on the user's safety when working on a construction site.

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