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Comparative analysis of engineering solutions against the shift of the upper part of the ladder when performing work at height

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Introduction. Modern construction is characterized by work at a height using stairs. The article presents various engineering solutions aimed at preventing injuries during such work.

Problem Statement. The objective of this study is to compare the available engineering solutions aimed at preventing the upper part of the ladder from shifting when performing work at height.

Theoretical Part. The work shows the ranking of the existing technical means that allow fixing the upper part of the ladder on the surface of the support and reducing the risk of sliding the upper part of the ladder on the support. It is shown that the structure fixed to the support has the least risk in ensuring the safety of work at height.

Conclusion. The article defines the most promising directions of development of technical solutions against shifting the upper part of the ladder.

Keywords: working at height, working on support, working from stairs, stairs sliding, falling from stairs.

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Introduction. In construction, a significant amount of work is performed at height. It is often carried out using ladders. The statistics of industrial injuries in the Russian Federation indicate that injuries when performing work at height account for about 25 % of all industrial injuries in Russia [1]. Most of them are related to construction works using extension ladders [2, 3]. As a rule, when falling from a height, including from a ladder, an employee receives serious injuries, including fatal ones [3, 4]. About 70 % of serious falls from stairs occur using portable ladders, and the most common cause of a fall is the sliding of a ladder under the user [5, 6].

Problem Statement. The cost of purchasing a ladder is small; the ladder is portable, has a low weight and is easy to operate. These things explain the widespread use of various types of ladders in the workplace. The ladder is irreplaceable in those places where there is no possibility for a bucket lift to drive near. In modern conditions of construction production, ladders will be an actual means of lifting to a height (support) for a long time.

When investigating the causes of human falls from ladders, the predominant role of the "human factor" is noted. Therefore, the improvement of technical measures aimed at ensuring the safety of work at height using ladders is relevant within the framework of the occupational risk management system. Safety measures that exclude or minimize the influence of the "human factor" are currently a priority.

In order to ensure the safety of work in mass production, engineering and technical means with a high degree of reliability are widely represented, which are installed on the lower ends of the ladders (metal shackles and pads made of non-slip material). Technical means against shifting the upper part of the ladder when performing work on a support in mass production are very few. At the same time, the available means are not sufficiently effective in all cases.

The aim of the research is to conduct a comparative analysis of engineering solutions against the shift of the upper part of the ladder when performing work on the supports of overhead communication lines (OCL) and overhead

power lines (OPL); to determine the most promising directions for the development of technical safety measures against the shift of the upper part of the ladder when performing work on the support.

Theoretical Part. It is possible to ensure the safety of work at height with the use of ladders by increasing stability by using the upper attachments, which are attached to the stairs by a fastening system (Fig. 1).

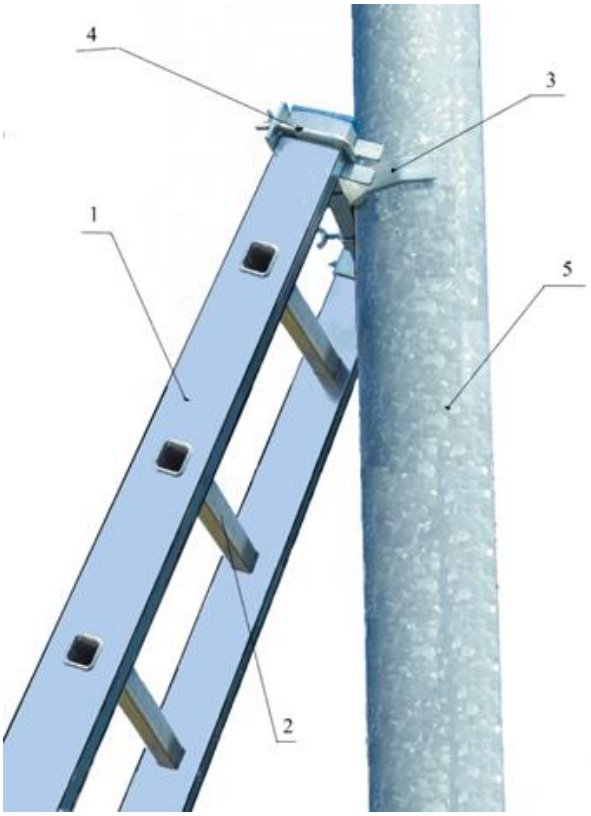


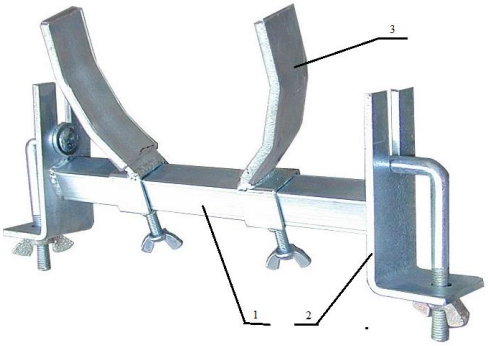
Fig. 1. Installation of a ladder with a nozzle to the support:
1 — ladder string, 2 — step, 3 — attachment,
4 — attachment of the nozzle to the ladder, 5 — support

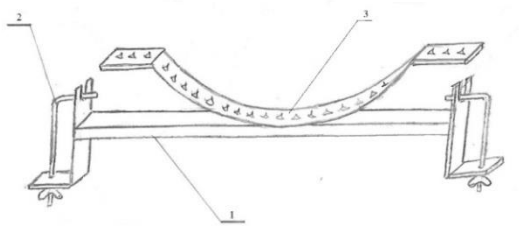
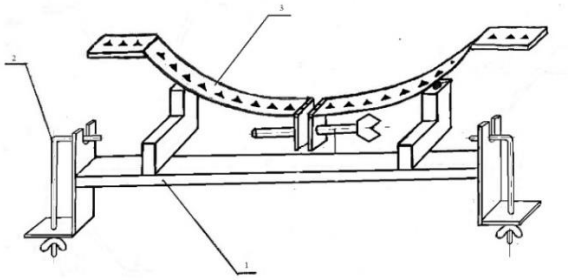
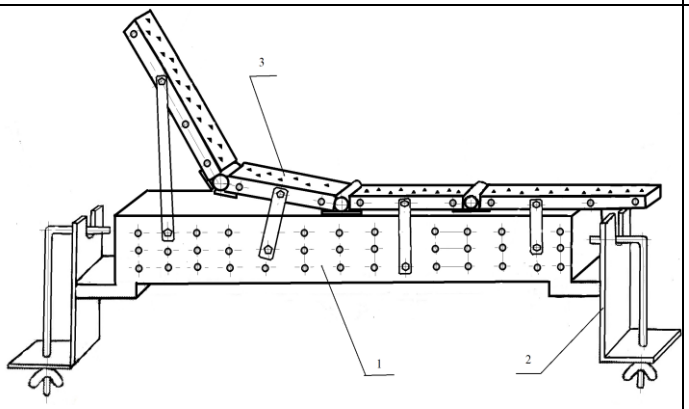
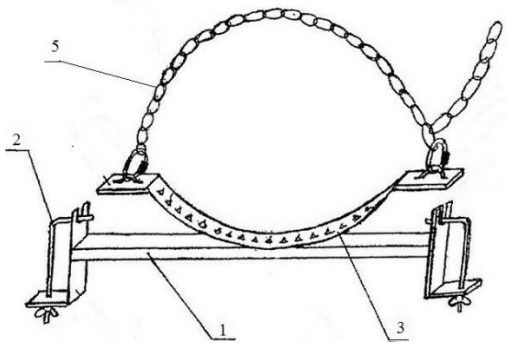
The types of attachments differ depending on the method of coupling with the support, the possibility of adjusting the coupling area, as well as the presence of built-in safety systems when performing work at height.

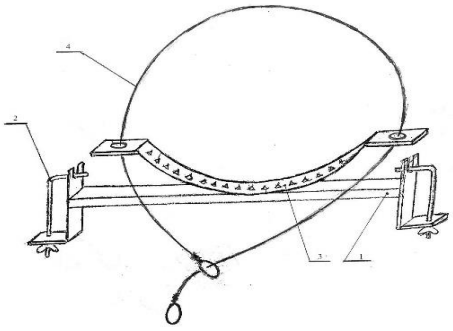
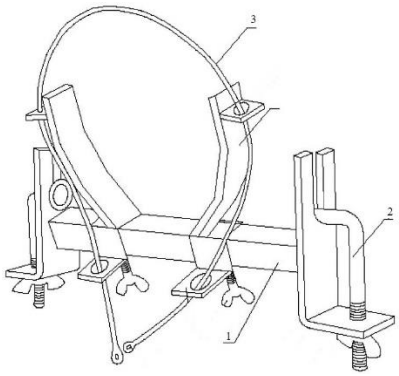
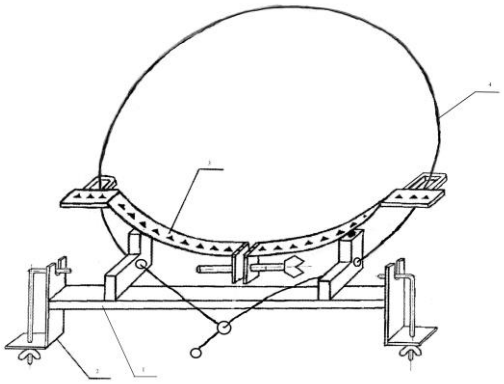
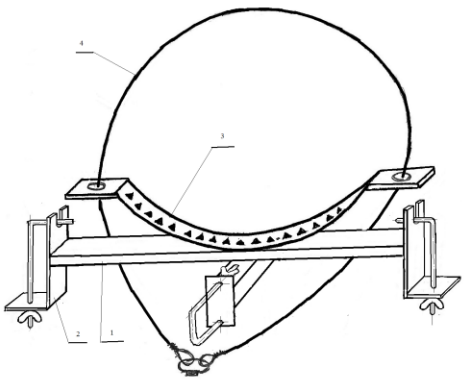
Table 1 shows the available types of attachments, which are grouped by the functional design and the method of coupling with the support [7–14].

Table 1

Attachments and functional design

Name	General view	Patent
1	2	3
Attachments to the ladder with a stop against shifting		Attachment for support on a pole / mast KRAUSE

Name	General view	Patent
1	2	3
		Patent for the utility model "Ladder attachment", Patent number:184480 [8].
		Patent for the utility model "Ladder attachment", Patent number: 193480 [9].
		Patent for the utility model "Ladder attachment", Patent number:202731 [10].
Attachments to the ladder with a stop and a ring chain		Patent for the utility model "Ladder attachment", Patent number:189558 [11].

Name	General view	Patent
1	2	3
Attachments to the ladder with a stop and an anchor loop		Patent for a utility model "Attachment to a ladder with an anchor device", Patent number:196601 [12].
		Patent for a utility model "Attachment to a ladder with an anchor point", Patent number: 185193 [7].
		Patent for the utility model "Ladder attachment", Patent number: 198464 [13].
		Patent for a utility model "Attachment to a ladder with a reinforced attachment for a ladder and an anchor device", Patent number: 202731 [14].
Notation to the figures: 1 — attachment on the ladder, 2 — fixing of the attachment to the ladder, 3 — stop; 4 — anchor loop, 5 — chain.		

The attachment with a stop and a chain will securely fix the upper edge of the ladder to the support. But before you do this, you need to climb the ladder. Since insurance against falling from a height while climbing the ladder is not provided, it is necessary to get it for this time [7,11–14].

Other attachment designs that do not have a rigid attachment to the support, have a reduced degree of safety, which is determined by the coupling force of the attachment, depending on its design [8–10].

The ladder attachment described in [8] is distinguished by its ease of use. The stop has spikes that provide grip with the support. The ladder attachments described in [9, 10] also have a stop with spikes, but the coupling area can be adjusted [15, 16] by changing the radius of the stops relative to the support.

The risk-oriented approach to occupational safety assessment involves the use of various mathematical models and methods that allow comparing risks and choosing the most effective solution [17, 18]. The solution to the problem of ensuring the safety of work at a height on ladders is one of the priorities in labor protection [19].

With a large variety of available engineering solutions that are aimed at improving the safety of work at height using ladders, there is still no universal effective engineering solution. When evaluating samples of equipment at the stage of their development, various engineering solutions can be applied in modern engineering practice, depending on the situations [20, 21].

The development of technical safety measures will minimize the role of the "human factor", reducing the risk of falling ladders from the supports.

Table 2 shows the ranking of technical means that allow fixing the upper part of the ladder on the surface of the support, as the risk of sliding the upper part of the ladder from the support decreases. So, for a ladder without an attachment, the risk of sliding the upper part of the ladder from the surface of the support R_1 will be the maximum, and the engineering solution in the form of an attachment to the ladder with a stop and an anchor loop will provide the minimum risk R_4 of all the proposed engineering solutions.

Table 2

Ranking of technical solutions as the risk of shifting the upper part of the ladder from the support surface decreases

Engineering solution	Ladder without an attachment	Attachment to the ladder with a stop against shifting	Attachment to the ladder with a stop and a ring chain	Attachment to the ladder with a stop and an anchor loop
Risk of slipping off the top of the ladder from the support	R_1	R_2	R_3	R_4
	$R_1 > R_2 > R_3 > R_4$			
Safety measures	There is no stability at the point of contact of the ladder with the support. In the process of climbing the ladder, it is necessary to have an anchor point for fixing the safety system.	The ladder with the attachment is stable against the support. In the process of climbing the ladder, it is necessary to have an anchor point for fixing the safety system.	When climbing the ladder, it is necessary to have an anchor point for fixing the safety system. The ladder is rigidly fixed with a support by means of a chain.	The device includes an anchor point. No additional anchor devices are required for safety when climbing and working at height.

Analyzing the engineering solutions safety, it can be argued that the attachments to the ladder with a stop and an anchor loop ensure maximum safety of the employees through the possibility of using a safety system to create an anchor point at a height without additional technical means. According to the authors, this conceptual direction of the technical solution is the most promising.

Conclusion

1. The article presents a comparative analysis of technical solutions that allow fixing the upper part of the ladder on the support surface.

2. The type of engineering solutions against the shift of the upper part of the ladder when working on a support is determined, which are the most promising from the point of view of ensuring safety when working at height. The ranking is carried out of technical means that allow fixing the upper part of the ladder on the surface of the support, as the risk of sliding of the upper part of the ladder from the support is reduced.

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Contribution of the authors:

V. A. Senchenko — formulation of the main concept, goals and objectives of the study; T. T. Kaverzneva — preparation of the text; S. L. Pushenko — scientific supervision, formulation of the conclusions; E. V. Staseva — analysis of the research results, revision of the text; N. V. Rumyantseva — preparation of the text, formulation of conclusions.