Safety of Mountaineering Systems in the Industrial Area

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Abstract. This paper is devoted to the safety of mountaineering systems, which are designed to prevent falls from a height. The purpose of the paper is to investigate the safety of fall arrest systems and their effectiveness. In addition, the study is to answer the question of whether mountaineering systems are used in the industrial area. This area requires the use of different mountaineering systems than in the case of sport mountaineering. As parks at heights are included in the list of particularly dangerous works, an analysis of systems protecting employees against falling from a height was undertaken. For this purpose, surveys were conducted to determine their correct operation and the degree of employee protection. Employees working in the profession of industrial mountaineer were defined as the research group. As a result of the conducted research, it is determined that employees use individual and collective protection measures. Respondents declared that the means they use work correctly and determine high effectiveness of protection against falls from a height. The systems themselves are built in the correct way and the respondents did not clearly indicate one dominant disadvantage of the mountaineering systems they use.

Introduction

Ensuring work safety at heights relies on specialized employee protection measures. Occasionally, the creation of specific procedures for working at heights is necessary to minimize accidents and near-accidents. The profession of an industrial mountain climber and relevant legal regulations in European countries were examined to establish employer obligations towards employees. Subsequently, all protective measures designed to safeguard the well-being and safety of individuals are outlined [1]. Mountaineering involves working at heights using suspension or support systems, distinguishing it from recreational mountaineering where the primary objective is reaching a peak or specific height with a single rope. Industrial mountaineering, in addition to ascending heights, involves undertaking specific work tasks. Industrial climbing can be conducted on platforms or suspended shelves using climbing ropes. However, the most common approach involves utilizing a safety harness connected to an anchor point via a rope [1-3]. Industrial climbers perform a range of activities, including facility inspections, window cleaning, facade maintenance and washing, repair and upkeep of high-voltage and telecommunications lines, installation and removal of signage and billboards, antenna and transmitter maintenance and repair, roof snow removal, renovation and construction work, and more. The profession of an industrial mountain climber demands employees to possess high physical fitness and climbing skills. It entails significant responsibility for assigned tasks and necessitates conscientiousness and meticulous adherence to safety measures. It is not suitable for individuals with a fear of heights, as the job entails meeting various mental and physical requirements [2].

Work at height is defined as work more than one meter above ground level. Such regulation has been introduced in many European countries. Carrying out work above this height is classified as particularly dangerous work. This determines special requirements for the employer because he must ensure supervision over the work carried out in this way and the persons designated for it.

Work supervision can be carried out in a variety of ways designated by the employer or the health and safety unit. The forms of supervision include, among others: periodic work inspections, inspections and the appointment of health and safety observers. The main task of health and safety observers is to supervise the work in real time and verify its compliance with occupational safety standards. This person should have a degree in safety science and/or appropriate training. The employer is also obliged to provide protective measures. In this case, protective measures are understood as collective and individual protection measures. In addition, the employer is obliged to conduct employee training. Its purpose is to determine the order in which tasks are to be performed and to specify the requirements for performing individual activities in the areas of occupational health and safety [1-4].

Personal protective equipment against falls from a height is crucial in protecting the human factor and is mainly designed to stop a fall from a height. The choice of protection measures depends on the type of activities performed. It must be selected individually for each type of work carried out [4]. The first type of protection against falling from a height are fall arrest systems. The main idea of this type of solutions is to limit the worker to the fall hazard zone, i.e. the length of the rope determined in such a way that the worker cannot get close to the edge of the building. The elements constituting such a system are: anchoring sub-assembly, connecting component, harness.

The second type of system is used when the worker is unable to stand without additional support. Such a system is necessary when it is necessary to give positioning while working at height. The elements that make up this type of system are: anchor sub-assembly, lanyard for positioning while working, harness. The use of this type of system allows to work in conditions where a given workplace generates a high angle of inclination of the surface. Its main difference from the accident prevention system discussed earlier is that the harnesses must have two attachment points. With this system, the safety line is in constant tension. This does not allow for spontaneous loosening of the rope and the distribution of masses and forces is transferred to the entire system. The third type of mountaineer protection system is used only in cases where it is impossible to eliminate the start of falling from a height. This type of system includes: anchor sub-assembly, connecting and damping sub-assembly, safety harness [5-7]. A very important aspect that should be taken into account when planning work at height and choosing the system needed for a given job is securing the workplace. Before starting work, it is also necessary to identify places of increased risk, which may directly translate into possible accident consequences.

In addition, it should be taken into account to equip the employee with personal protective equipment in accordance with the risks that occur in a given work environment. The most commonly used personal protective equipment when working at heights are:

- head protection – they are designed to protect the employee's head against elements falling from a height,
- lower limbs protection equipment – protect the lower limbs against mechanical injuries and/or rotating elements of machines and devices that are components of a given workplace,
- upper limb protection equipment – they are designed to protect the upper limbs against threats,
- protective clothing – is designed to ensure thermal comfort and protect the employee from weather conditions.

Their use is variable depending on the type of work carried out and the place of performance. In order to make the right choice, a risk assessment should be made taking into account all hazards and variables. Changing working conditions are a key aspect determining the selection of personal protective equipment. After determining and selecting, the employee should be equipped with all necessary means for safe performance of work. This is the employer's obligation in most European countries, defined and specified in the Labor Code. Each employee should have their own personal set of protective equipment, which should be used only by a particular unit. It is a good practice for enterprises to apply work safety procedures and specify in them the use of protective measures in specific conditions and types of work. They are voluntary and are not conditioned by the legislator.

Industrial high-altitude work is a high-risk endeavor. For this reason, the equipment utilized for such tasks must be of superior quality and subject to constant supervision to identify potential flaws and malfunctions [8-10]. The primary destructive factors encompass corrosion [11-13], including biocorrosion [14], as well as wear [15-17]. These factors can be mitigated by employing appropriate materials, such as metals [18-20] and alloys [21], and by executing welded connections with precision [22-24]. Coatings [25-27] and suitable surface layers [28], including those with modified morphological and technological features [29,30], also offer effective protection. The proper design and construction of equipment for high-altitude work should also incorporate energy consumption reduction [31] throughout production and operation, as well as subsequent recycling efforts [32-34]. Accomplishing this necessitates the utilization of appropriate design methodologies [35-37] and the optimization and stabilization of processes [38-40], including nonparametric [41-43] and resampling techniques [44,45].

Experiment and Methods

According to the study, it is necessary to determine the correct operation of mountaineering systems and the degree of employee protection against falling from a height. For this purpose, a survey questionnaire was created. In this paper, the areas of the survey directly related to mountaineering safety systems used in industrial work at heights were analyzed. The analysis is based on two basic research questions (Q1 and Q2):

Q1. To what extent do mountaineering systems protect an employee against falling from a height?
Q2. Do the mountaineering systems used work properly?

The survey was developed using a web form that allowed the respondents to generate a link. After launching it, a survey opens with four questions relating to the metrics and ten survey questions. The research was conducted from March 3, 2022 to March 10, 2022. 35 industrial mountaineers participated in the study. Mountain climbers came from various industries and performed various activities. Therefore, the scope of their duties was variable, which determines the credibility of the conducted research in terms of the use of various types of fall protection systems. The first question of the survey concerned the percentage structure of respondents' gender. The results were as follows: men accounted for 94.3% and women for 5.7%. The low number of women is conditioned by the specificity of the industry.

The second question refers to the age of the respondents. This question has been divided into four possible answers within the following ranges: 18-28 years - this answer was marked by 11 people, which is 31.4%; 11 persons declared themselves to be aged 29-39 in this group, which constitutes 31.4%; 40-50 years old, this range is 7 people – 20.0%; over 50, marked by 6 people (17.1%). The next question refers to the education declared by the respondents. Most people indicated that they had secondary education, about 20%. Secondary (vocational) education was declared by 22.9%, higher education was indicated by 14.3%, primary education by 42.9% The last question concerns the seniority of the respondents in the mountaineering industry, this question is one of the key ones because they define the work experience of individual respondents. The largest number of respondents declared that their seniority is over 20 years and they constitute 28.6%. The group with 5 to 10 years of service constituted the second largest group, accounting for 20% of all answers. The distribution of responses between the individual ranges is shown in Fig.1.

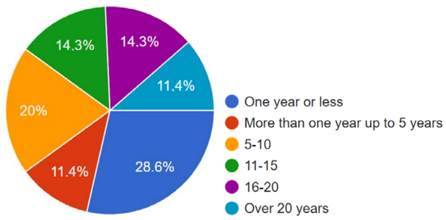

Fig.1. *Percentage structure of seniority in the industrial construction industry.*

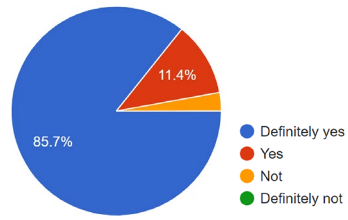

Fig.2. *The structure of the answer to the question about the effectiveness of the use of mountaineering systems.*

The next researched issue is the question of the effectiveness of mountaineering systems. The overwhelming majority of 85.7% marked the answer definitely "yes". This determines that employees consider mountaineering systems to be effective. The answers provided by the respondents confirm that the mountaineering systems are working properly. The graph is shown in Fig.2.

The question regarding the degree of protection of the employee against falling from a height was crucial in the hypothesis – mountaineering systems significantly protect the employee against falling from a height. Respondents confirmed that fall protection systems completely protected them, such an answer was selected by 74.3%. A large proportion of 22.9% believe that these systems protect the employee against falling mostly. None of the respondents marked the answer at all, as shown in Fig.3.

The question about the correct operation of the mountaineering systems showed that 77.1% rated them very well, while 20% answered well. Which means that the employees assess the correctness of operation at a high level – as shown in Fig.4. A high percentage indicates that employees trust the mountaineering protecting systems that protect their health and/or life against falling from a height. This is an important aspect of work because it determines the sense of security, which is considered fundamental in human life. The hierarchy of needs developed by A. Maslov shows it as a key enabling the satisfaction of higher human needs, but it is impossible to achieve them without satisfying lower levels [46].

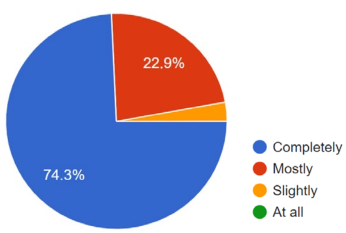

Fig.3. *Structure of answers to the question about the degree of protection of employees against falling from a height.*

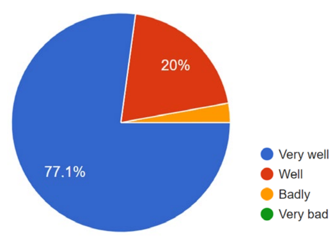

Fig.4. *Percentage structure of answers to the question on the correct operation of mountaineering systems.*

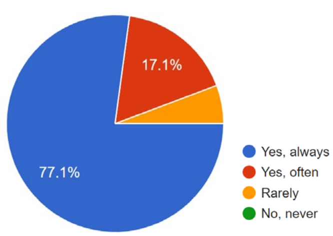

Fig.5. *Percentage structure of answers to the question on the use of the system against falling from a height by the respondents.*

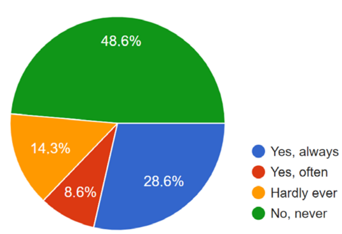

Fig.6. *Percentage structure of responses to the question on admitting an employee to work without protective equipment.*

The question relating to the use of mountaineering protecting systems by workers is a key question relating to the hypothesis – Workers use mountaineering protecting systems correctly. 77.1% answered yes, always. 17.1% answered yes, often. The mere fact that the employer provides protective measures does not determine their use by individual employees. This presupposes that employees use fall protection measures provided by the employer. The percentage structure of answers to this question is presented in Fig.5.

The next issue examined was the employer's admission without fall protection systems. This question showed that it varies depending on the approach to work and the responsibility of the employer. About 48.6% of respondents to the question: Does your employer permit you to work without any of the mountaineering protecting systems from falling down the higher answered "no, never" (Fig.6). Answer "yes", always marked 28.6%, which is a very disturbing signal, because endangering the life and health of employees is widely accepted in some workplaces. In this case, a number of actions should be taken to increase the employer's awareness of the risks of mountaineering. Particular attention should be paid to the aspects of occupational health and safety in these plants by the occupational health and safety unit. This parameter may also indirectly indicate that the cell is operating incorrectly.

The risk in the mountaineering industry, according to the respondents' answers, is at a very high level, as much as 73.5% of the respondents indicated this answer, while 20.6 indicated the answer high. Which means that employees are highly aware of the use of protective measures – Fig.7.

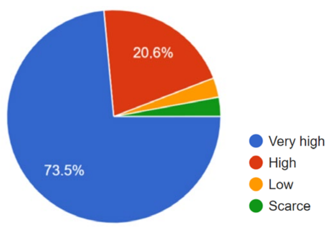

Fig.7. *Percentage structure of responses to the question regarding employees' awareness of the risk of accidents in industrial mountaineering.*

When asked about the weakest point of the whole system, the answers were as follows:

- anchoring subassembly – 14.3%
- safety cables – 77.1%
- hip harness – 11.4%
- connecting and absorbing subassembly – 8.6%
- safety harness – 22.9%

Therefore, it can be concluded that the majority of respondents notice that the weakest point in the entire fall protection system is the safety ropes. These ropes must be replaced periodically. If the equipment is assigned individually to an employee, it must be replaced after 5 years. When equipment is transferred between individual employees, its time interval is defined as one year. Ropes should be visually inspected before each use.

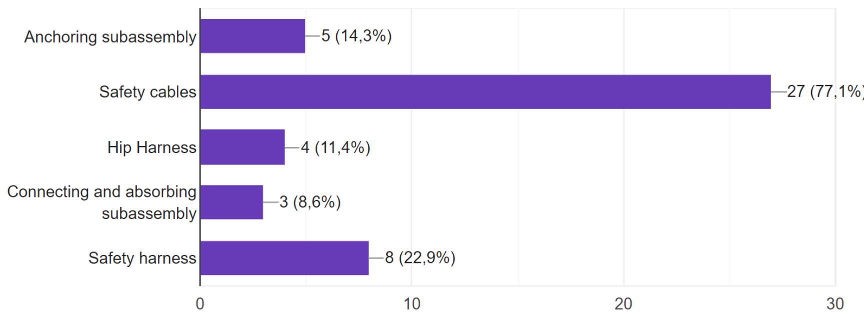

Fig.8. *The structure of the answer regarding the indication of the weakest point of the fall protection system.*

Summary

Worker fall protection systems used in the industrial mountaineering industry work properly. Their use is variable depending on the working conditions and the angle of the ground inclination. Sometimes they have to ensure the correct body position. This requires an individual approach to each work carried out and adaptation to weather conditions - if the work is carried out outside. Employers, on the other hand, are obliged to provide all means of protection, including personal protective equipment. The conducted research showed high awareness of the use of fall protection systems and the systems work properly. The respondents also noticed that these systems protect the employee to a large extent against falling from a height. Falling from a height often has serious health consequences, so remember to periodically check the condition of individual elements of the entire system. Particular attention should be paid to the safety ropes and their technical condition.

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