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A Latest Equipment for Safe High-Altitude Operations

Shou Yuan*, Chen Chen

The Meteorological Equipment Center of Hunan Province, Changsha, 410007, China
**Corresponding author: 1270436000@qq.com*

Abstract: *High-altitude operations are essential in various industries, including construction, maintenance, telecommunications, and energy. These tasks often involve working at heights that can pose significant risks to workers' safety. To mitigate these risks, the meteorological department has continually sought advancements in equipment and technology that can enhance safety and efficiency, especially when engineer have to finish device maintenance in observatory. This paper delves into the latest equipment for safe high-altitude operations, highlighting the innovations that are transforming this sector.*

Keywords: *High-altitude operations; Safety equipment; Automated systems; Meteorological observation*

1. Research Background and Literature Review

In order to gain real-time and accurate meteorological observation data, sensors with multiple meteorological observation elements have been deployed at every country and city observation site. Among these sensors, wind speed and wind direction must be installed on an observation tower more than 10 meters above ground base on observation specification from China Meteorological Administration [1]. In typical wind observation site the height have to set more than 30 meters.

Figure 1: Meteorological observation tower

As Shown in Figure 1， that under the situation that wind observation sensor have to deployed in a height that staff may face risk of unstable surfaces, strong winds, falling objects, and other hazards can lead to serious accidents and injuries. Therefore, there is a pressing need for advanced equipment and technologies that can improve safety outcomes. The significance of this research lies in identifying and

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discussing the latest developments in high-altitude safety equipment, which can contribute to reducing accidents and injuries in the workplace.

Previous research has focused on various aspects of high-altitude operations, including safety protocols, risk assessment, and the use of safety equipment. Kyle[2] and others present a virtual reality-based training as a training and certification approach. Nataraj B[3], Pigi[4], Jin[8] and others find out that YOLOv7 able to provide a safety detection method that establish actual scenarios or data set to prevent risk. Nataraj B[3] and Sharjeel[5] Et cl adopt deep learning to evaluate safety rules, consider and monitor staff working environment and safety condition. Neha[6] finds out smart wearable device able to address the limitations of unreliable communication, low accuracy, unavailability of real-time data issues. Zhiheng Chen[7] and others use neural network to set human behavior patterns to forecast fall accident risk. Sujatha[9] Et cl invent a helmet with Bluetooth, WiFi and GPS technology and remote sensor to provide real-time health monitoring. Peng Liu[10] Et cl demonstrates potential of eye-tracking technology in safety training and high height risk prevention.

2. Current Safety Strategies

From current working status, high height safety strategies can be divided to three methods, training, specialized equipment, and monitoring systems. Pre-operation planning involves assessing the specific hazards of the site, selecting appropriate equipment, and developing emergency response plans. Comprehensive training programs, including physical conditioning, technical skills, and crisis management, are essential for personnel to handle high-altitude conditions confidently. Specialized gear, such as breathing apparatus, insulated clothing, and fall protection systems, is crucial for maintaining functionality and safety at high altitudes. Advances in materials science have led to lighter, more durable equipment that enhances worker mobility and protection. Real-time monitoring of vital signs and environmental conditions, coupled with reliable communication systems, allows for prompt response to emergencies. Wearable technologies and satellite communications are increasingly being integrated into high-altitude operations to ensure continuous oversight and rapid intervention.

There are literature believe high technology may bring benefit, however, newly technology greatly rely on additional resource to finish work, such as internet server, network, data exercise and so on. Which may introduces more risk when staff rely on complicated designed gear.

3. Overall design

The meteorological observation lasts 24 hours a day, 365 days a year, no matter how risk the weather is, the observatory equipment maintenance staff have to guarantee meteorological observation device working properly. In that case, the observatory equipment maintenance have to face much more risk when they working in extreme weather, such as rainstorm, tornado, blizzard and so on. Considering the observation tower is a steel structure, and it is very difficult to climb when extreme weather happening. Newly technology device which rely on internet, data base, cloud platform has a large possibility cannot work properly, it urges to invert a new high-altitude safety working device counting on physical devices.

Figure 2: Protective clothing

To make sure staff have the most flexible and comfortable device, the very and first thing is to

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guarantee staff's high-altitude stress point. Protective clothing is widely used and required as a regular tool have to be equipped. Generally a protective clothing like figure 2 presents adopts ergonomic design such as flexible materials to enhance mobility, meanwhile clothing uses five-point force structure, concentrate main force structure on hip, waist and shoulder. That ensures high-altitude pressure on human body can dispersed to various parts and prevent workers unable to complete work.

Full-body harnesses are designed to distribute the force of a fall across the worker's body, reducing the risk of injury. These harnesses are made from high-strength materials, and equipped with shock absorbers to further mitigate the impact of a fall. Modern full-body harnesses also incorporate features such as adjustable straps and padding to improve comfort and fit. This ensures that workers can wear them for extended periods without discomfort, increasing compliance with safety protocols.

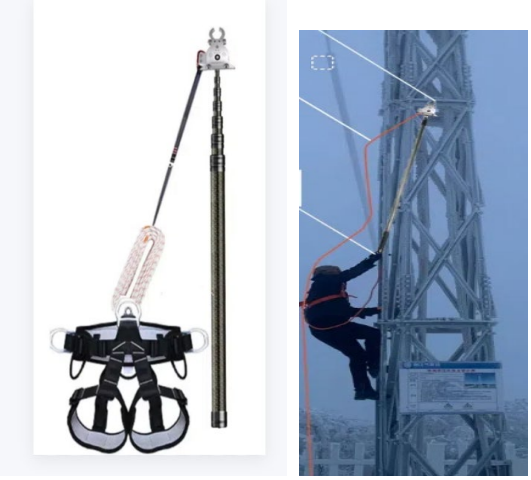

Figure 3: Anchor point installation device

To maximize safety of high-altitude work, a fixed stress point device designed in Figure 3 can greatly help working engineer set working points and flexibly adjust stress and safety heights, which has been invented and named as anchor point installation device. Due to physical mechanical buckle design, working staff can easily lock the anchor point positioning device in their hand through remote control device, after the first anchor point set, the working staff able to clime higher and use anchor point device repeat previous operation. During the process of work, the first advantage is the working staff can easily climb because the safety rope connected to the anchor point at back pack, the second advantage is the great safety when working staff combine installation of safety clothing and rappelling hook rope, the third advantage is anchor point installation device can leave anchor and spare rappelling rope on wind observation tower, to convenient user quickly complete installation of safety device. Once the anchor point set, it can be seen as an aerial platform has been set.

Figure 4: Fixed anchor point connector

In order guarantee the stability and reliability of the fixed anchor point connector, Figure 4 fixed anchor point connector the proposed safety locking mechanism integrates several innovative features to address these limitations. The design incorporates, the first is advanced Materials, utilization of high-strength, corrosion-resistant alloys for critical components to enhance durability and resist physical tampering. The second is Multi-Stage Locking Mechanism, a combination of mechanical and electronic locking stages, where each stage must be sequentially activated to unlock the device.

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Considering the safety device have to work under the situation of extremely weather, it has been tested of environmental durability to assess operational capabilities. Specifically, it demonstrates a tensile strength of 300kN, and consistent performance under different weather conditions.

After test anchor point installation device in different weather working condition, the most stable working method is to adopt physical buckle form and formulate the lock. During experiments of fixed anchor point connector under the situation of various weather, it is found that blue-tooth connection performs unreliable in heavy rain. One prominent disadvantage is Bluetooth remote controller have possibility cannot work properly, the other prominent disadvantage is worker have to free one hand to finish remote control process, which brings danger and uncertain risk that remote controller may fall or their hand might injured because of bad weather. When it comes to high-altitude work, it is difficult for staff to complete actions other than protecting their own safety. Industrial designed integrated Bluetooth remote control into voice control, it turns out worse performance when encounter extremely weather. The same thing happens when trying to connect remote controller adopts network. The final result of experiment is that the physical structure is the most stable device under severe weather conditions.

4. Discussion

The success of anchor point installation device mainly attributed to its advanced materials and manufacturing techniques enables a robust and precise locking system, and this device demonstrates a new way of thinking about use objects to guide user. As a skillful and dangerous work, high-altitude working usually rely on professional skill or proficiency of staff to finish job. However, it is hard to train enough professional staff or rent skillful employee to finish wind tower maintenance work. Therefore a simply operate tool is crucial to save training cost and easily storage in every observation site. The anchor point installation device can add more function or components to accomplish monitoring human health condition or add alarm function. At current stage the most important is to optimize operation procedures and improve safety factors.

5. Conclusion

This paper presents a newly invented high-altitude work tool that named anchor point installation device to improve the safety factor of workers working at heights. By examined various design ideas it chooses mechanical combines protective clothing to minimize the risks associated with electronic devices, and promotes a way of thinking that rely on tool to tackle problem instead of training.

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