Collaborative Safety System for Self-propelled Elevating Work Platforms Achieves ANSHIN and Well-being Workplace for Workers and Managers

Mori T[1]., Nobuhiro M[2]., Nakai T[2]., Dohi M[2].

1 Daiwa House INDUSTRY CO., LTD.
2 IDEC CORPORATION

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ABSTRACT

Construction sites involve numerous elevated tasks and self-propelled elevating work platforms, a kind of construction machine, that raise or lower the platforms are widely used. When raising the platforms, there are risks of the worker failing to notice the proximity to overhead structures and worker being trapped between the platform's handrail and the overhead structure. Historically, safety has relied primarily on human attentiveness. However, serious or fatal accidents have occurred in the past.

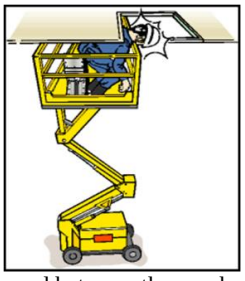
To address this issue, we have introduced a collaborative safety system for self-propelled elevating work platforms, incorporating the concept of collaborative safety. The system is equipped with a three-position enabling switch, an ultrasonic sensor and an anti-defeat function. The ultrasonic sensor measures distance to overhead structures and automatically stops the platform when the distance shortens below a predetermined distance. In case of hazardous event, the three-position enabling switch utilizes ergonomic reaction of surprised worker to stop the platform. In addition, as an anti-defeat function, the system also has a periodic check function to ensure that the system is working properly.

The implementation of collaborative safety system based on the collaborative safety concept not only reduces the risks of occupational accidents, but also makes work easier, increases concentration levels on the tasks and enhances a peace of mind, ANSHIN. Consequently, ANSHIN and well-being workplace is achieved and both workers and managers have been able to work in a positive psychological state.

1 INTRODUCTION

At construction and civil engineering sites, there are numerous tasks that need to be performed at elevated heights. For example, at construction sites, there are tasks such as plumbing and wiring that are carried out near overhead structure. For such elevated work, self-propelled elevating work platforms which are construction machines equipped with a working platform that serves as a foothold for the workers are widely used.

However, when a worker raises the platform, attention is divided between raising the platform and checking the surrounding situations. And due to the inadvertent, such as thinking about the next task or preparing work tools, workers may fail to notice the presence of overhead structures like beams. As shown in Figure 1, serious or fatal accidents have occurred in the past where workers have trapped their hands, arms, bodies or heads between the overhead structure and the handrail of the platform, when the platform was raised.



Trapped between the overhead structure and the platform [1]

Trapped hand

Head contact

Figure 1. *Examples of accidents on self-propelled elevating work platforms*

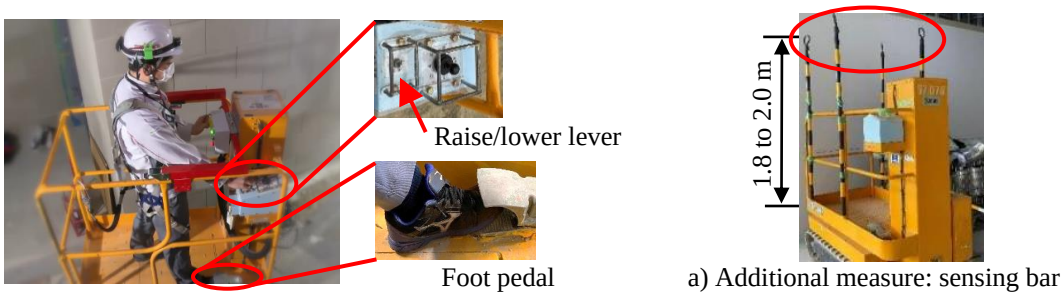


***Figure 2**. Examples of safety measures taken so far*

2 Safety measures taken so far

The safety measures shown in Figure 2 have been implemented so far for self-propelled elevated work platforms. One is a raise/lower lever. When seen from the operator's viewpoint, tilting it backward raises the platform, tilting it forward lowers the platform. And when released it from the hand, the lever returns to the center position. The other is a foot pedal. This foot pedal is a two-position type, OFF when not depressed and ON when depressed, and it allows raising or lowering of the platform only when depressed. To actually raise/lower the platform, it is necessary to simultaneously operate raise/lower lever and depress the foot pedal. To stop the platform, either release the hand from the lever or the foot from the foot pedal.

Additionally, sometimes 1.8-2.0m sensing bars are implemented as shown in Figure 2 a). In this case, since the bar contacts with the overhead structure before the worker, it becomes easier for the worker to notice the proximity of the overhead structure and increasing the possibility of avoiding contact with the overhead structure.

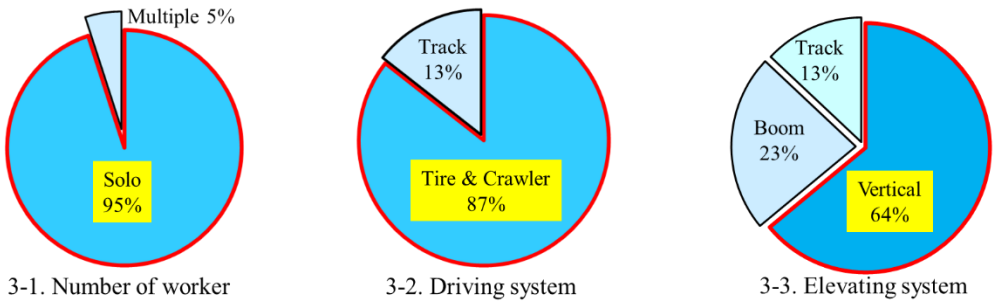
3 Three ‘situations’ and three ‘causes’ relating to the past accidents

Despite implementing the safety measures shown in clause 2, serious or fatal accidents have occurred in the past. We shall analyse these serious or fatal accidents in this clause.

3.1 Three situations of the past accidents

Based on an original study of accident data for self-propelled elevating platforms over 10 years, accident situations were classified into three categories.

- As shown in Figure 3-1, 95% of accidents occurred when one worker was on the platform. This is considered that when there are multiple workers on the platform, each worker can be responsible for raising and lowering the platform and checking the surrounding situation separately. However, when there is only one worker on the platform, he has to raise and lower the platform and check the surrounding situation simultaneously, therefore his attention is divided.
- As shown in Figure 3-2, the tire and crawler type of the driving systems accounted for 87% of accidents. This is considered that the truck type is often used outdoors, while the tire and crawler type is often used indoors. Therefore, it has a highly probability of coming into contact with and being trapped by overhead structure than the truck type.
- As shown in Figure 3-3, 64% of accidents were vertical elevating type. This is because the vertical elevating type is often used indoors and in confined spaces, where it has highly probability of coming into contact with and being trapped by overhead structures.



3-1. Number of worker 3-2. Driving system 3-3. Elevating system

***Figure 3**. accidents situations of self-propelled elevating work platforms*

3.2 Three causes of the past accidents

The causes of the accidents were identified and categorized as ‘inadvertent’, ‘ergonomic reaction’ and ‘defeating’ as described below.

3.2.1 Cause 1: inadvertent

Particularly in cases of solo operation, the worker needs to simultaneously operate the raising/lowering of the platform and check the surrounding situations, leading to divided attention. Furthermore, an inadvertent can arise due to habituation caused by repetitive work.

3.2.2 Cause 2: ergonomic reactions

If a worker's head unexpectedly comes into contact with the overhead structure during the raising of the platform, there may be instances where the worker is unable to release their hand from the raise/lower lever or their foot from the foot pedal. Through experiments conducted by our company involving 12 individuals and interviews with 4 injured workers, it has been confirmed that the ergonomic reactions differ depending on how the head makes contact with the overhead structure. The results are as follows:

A) Mode 1: When the overhead structure comes into contact with the forehead
As shown in Figure 4 a), the worker tends to lean backward, resulting in the possibility of their hand and/or foot becoming released from the raise/lower lever and/or foot pedal.

B) Mode 2: When the overhead structure comes into contact with the top of the head
As shown in Figure 4 b), the worker is pushed down from above, and in an attempt to resist or withstand the impact, the worker may tense their limbs, resulting in the possibility of being unable to release their hand from the raise/lower lever and foot from the foot pedal.

C) Mode 3: When the overhead structure comes into contact with the back of the head
As shown in Figure 4 b), when the worker is pushed on the back of the head, causing them to bend forward, and in an attempt to resist or withstand the impact, the worker may tense their limbs, resulting in the possibility of being unable to release their hand from the raise/lower lever and foot from the foot pedal.

Depending on the worker's height, when operating the raise/lower lever and foot pedal, they often stand upright or slightly leaning forward. Therefore, in cases of inadvertent resulting in contact with overhead structure, it is highly likely to be Mode 2: When the overhead structure comes into contact with the top of the head, or Mode 3: When the overhead structure comes into contact with the back of the head. It was demonstrated that in such situations, the ergonomic reaction causes the worker to unconsciously resist, preventing them from releaseing their hand from the raise/lower lever and/or foot from the foot pedal, leading to the occurrence of accidents.

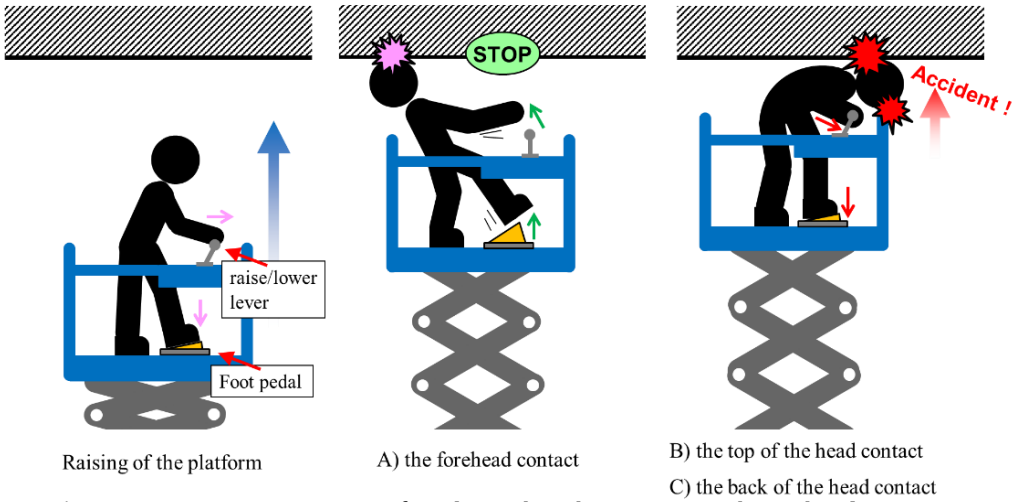


Figure 4. *Ergonomic reactions of workers when they contact with overhead structure*

3.2.3 Cause 3: defeating

Although it should not happen, some workers find the operation of the foot pedal cumbersome and, as shown in Figure 5, use familiar tools or materials to fix the foot pedal in the depressed state, simulating having their foot on it. As a result, the safety function of stopping the platform by releasing the foot from the foot pedal is compromised when necessary.

It was confirmed that a combination of several of these causes can lead to serious or fatal accidents.

***Figure 5**. Example of defeating foot pedal*

4 Countermeasures

In considering countermeasures against the three situations and three causes shown in Clause 3, in addition to the existing safety measures, we incorporated the concept of collaborative safety, which is gaining implementation in construction sites. [2]

4.1 Countermeasure 1: against inadvertent

As shown in Figure 6 a), an ultrasonic sensor was implemented to detect the proximity of overhead structures. The detection area of the ultrasonic sensor oriented upwards. When the ultrasonic sensor detects an overhead structure, it stops the raising of the platform. Additionally, even if the ultrasonic sensor fails to detect a complex shape of overhead structure, as described in clause 3.2.2, there is a high possibility that a worker who comes into contact with an overhead structure will bend forward. Then, as shown in Figure 6 e), the ultrasonic sensor can detect the worker and stop the raising of the platform, preventing worker trapped between the handrail and the overhead structure.

4.2 Countermeasure 2: against ergonomic reaction

In addition to the foot pedal, a three-position enabling switch (hereafter 3P-enable) was implemented as shown in Figure 6 b). 3p-enable is operated by the hand opposite to the hand operating the raise/lower lever as shown in Figure 6 c). As shown in Figure 7, a typical switch has two positions: on/off. The 3P-enable has three positions: off/on/off. As an ergonomic reaction, when surprised, a worker may either release or held tightly their hand. As shown in Figure 8 a), in case of contact with the overhead structure without 3P-enable, the worker may tense their limbs and be unable to release the raise/lower lever and the foot pedal, resulting in a serious or fatal accidents. As shown in Figure 8 b), in case of contact with the overhead structure with 3P-enable, even if the worker may tense their limbs, 3P-enable will turn OFF and stop the platform. Utilizing this ergonomic reaction as a safety measure, the 3P-enable can be stopped not only when the hand is released but also when it is held tightly.[3][5][6][7]

Although modifying the foot pedal to a three-position type was considered, in such a case, the position of the hand opposite to the one operating the raise/lower lever would not be fixed. Therefore, there is the possibility of the hand being trapped between the overhead structure and the handrail. Then, the 3P-enable was implemented to fix the positions of both hands, requiring simultaneous operation of the raise/lower lever and the 3P-enable with both hands. As a result, the risk of trapping hands between the overhead structure and the handrail is considered to have been eliminated.

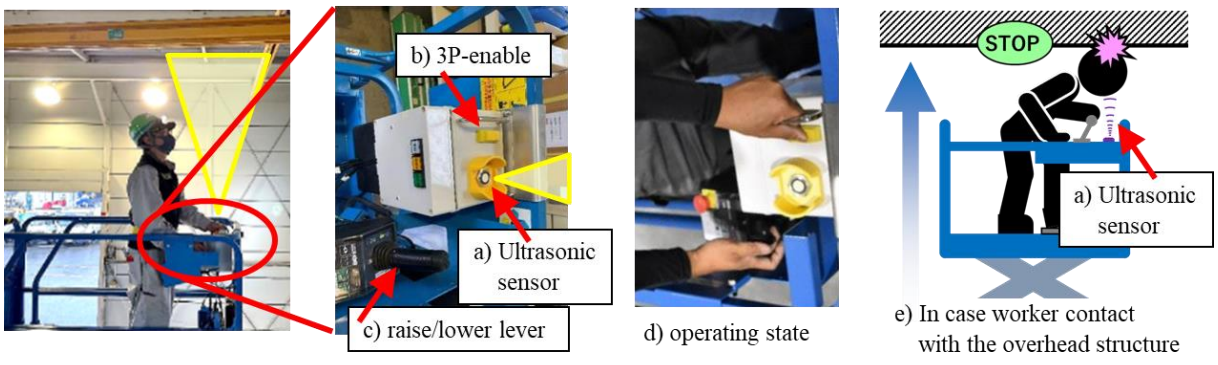


***Figure 6**. Examples of safety measures based on the collaborative safety concept*

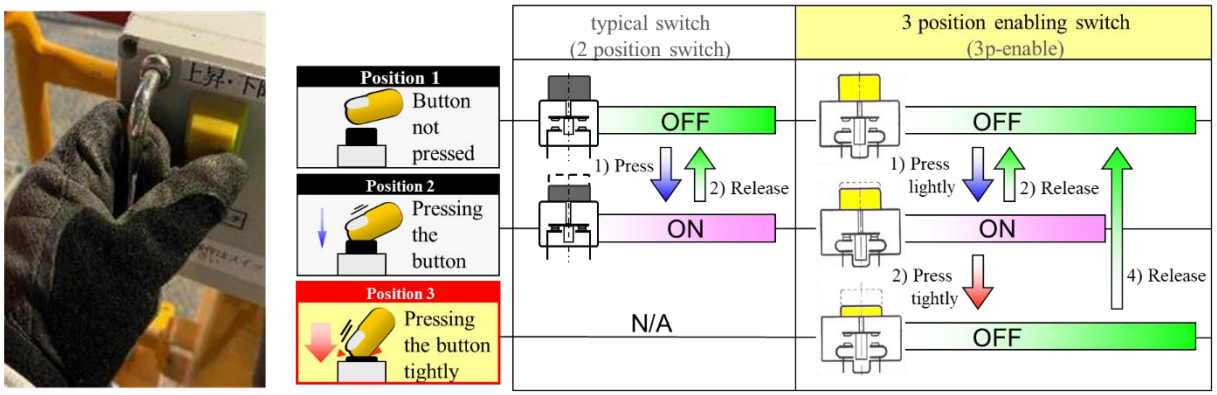


***Figure 7**. Differences between operating typical switch and three-position enabling switch*

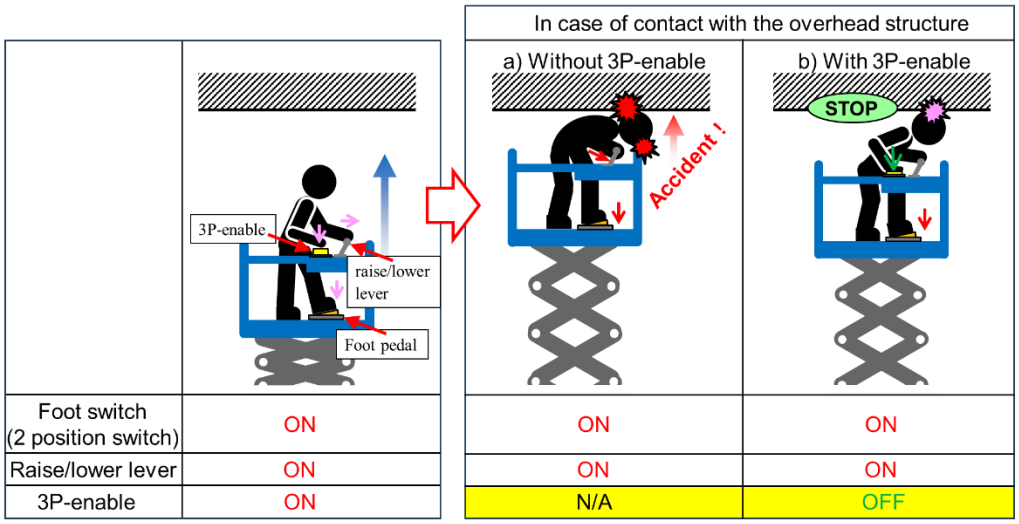


***Figure 8**. Differences with and without 3P-enable when worker contacts with overhead structures*

4.3 Countermeasure 3: against defeating

A monitoring function was implemented to detect the defeating of the raise/lower lever, foot pedal and the 3P-enable. Typically, the platform is not operated continuously for more than one minute. Therefore, a monitoring function was implemented that stops the platform if the operation continues for more than one minute. For the worker want to move the platform again, they must first release the raise/lower lever, foot pedal and 3P-enable, and then operate them again. With this function, if the system is defeated as shown in Figure 5, the effort required to periodically release and operate again the raise/lower lever, foot pedal and 3P-enable will be increased, and making it worker cumbersome to use the system. Therefore, this monitoring function reduces the motivation for defeating the system.[4]

5 Effects of introducing collaborative safety system

Before and after the introduction of the collaborative safety system described in clause 4, a questionnaire survey was conducted with 48 managers and 78 on-site workers. The results are shown in Figure 9.

- Both managers and workers perceived the effectiveness of the automatic stopping function provided by the ultrasonic sensor.
- Both managers and workers felt a particular improvement in concentration levels.
- Workers felt a peace of mind, ANSHIN.
- Workers felt the work easier. it is also possible that their motivation to defeat the system decreased as they could concentrate on the work.

As these results show, the positive effects of introducing collaborative safety system are confirmed and ANSHIN and well-being workplace is achieved.

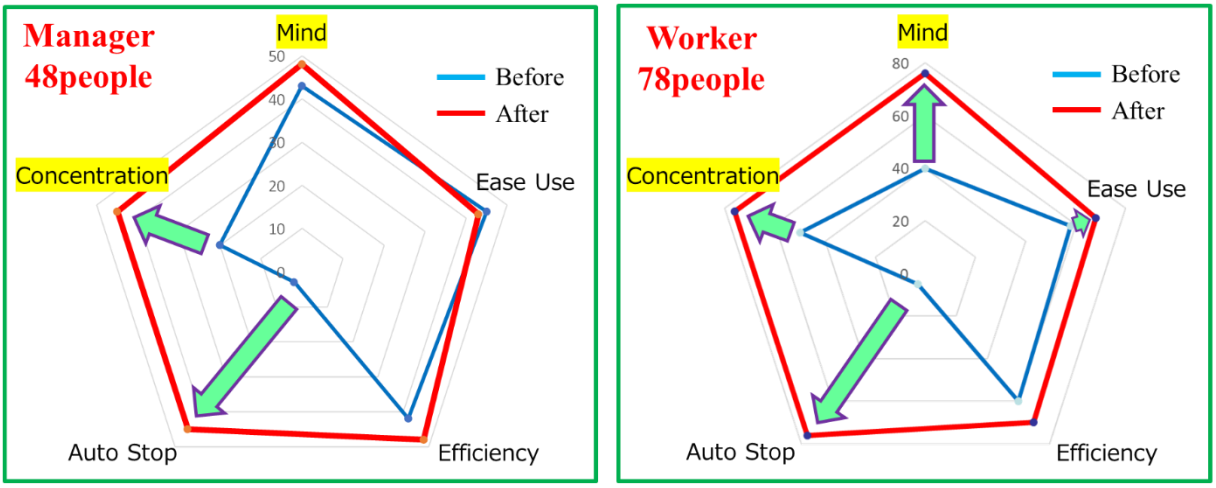


***Figure 9**. Results of questionnaire survey before and after the introducing collaborative safety system*

6 Conclusion

By introducing collaborative safety system for self-propelled elevating platforms at construction sites, we confirmed its effectiveness in achieving ANSHIN and well-being workplace for both workers and managers. Going forward, we plan to widely promote the adoption of this self-propelled elevating work platforms in the construction sites and facilitate the social implementation of collaborative safety/Safety 2.0. Additionally, we will continuously measure and improve its effectiveness by obtaining feedback from work sites, ultimately realizing ANSHIN and well-being workplace for both workers and managers.

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