Matching calculation of accidental movement protection device for elevator Car

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Abstract. The cage accidental movement protection system is an important protection system of elevator. The basic principle and structure of the cage accidental movement protection device are described. Combined with the whole process from accidental movement of the cage to the operation of the protection device, the theoretical calculation and judgment principle of the accidental movement of the cage protection device are introduced. Aiming at the requirement of the matching calculation of the accidental movement protection of elevator car, the selection of several key parameters which affect the matching calculation of the accidental movement protection of elevator car was proposed. The influence of several key parameters on the matching calculation is analyzed, and the parameter selection is discussed based on relevant standards, and feasible solutions are proposed. These schemes provide a reference for the selection and matching calculation of accidental movement protection devices.

1. Introduction
In recent years, with the improvement of living standards and the advancement of urbanization, more and more high-rise buildings have been built around the country, and the use of elevators has become more and more. Elevators have become an indispensable means of transportation, and their safety performance has been more and more concerned by people. Accidental movement of the elevator car may lead to the risk of shearing or squeezing of passengers entering and exiting the car [1]. Therefore, on July 16, 2015, the National Standardization Administration committee officially announced the GB7588-2003 "Safety Specifications for elevator manufacturing and installation" no. 1 amendment, which proposed that the elevator should have a device to prevent accidental movement of the car or stop the accidental movement. This device is often referred to as the protection device when the car moves unexpectedly and becomes one of the main safety protection devices of the elevator. Then on June 6, 2016, the "Elevator Type Test Rules" (TSGT7007-2016) was published to provide for the type test of the elevator cage accidental movement protection device (UCMP device, the same below). With the development of type test of UCMP device, its working principle, theoretical calculation and key parameter selection are worth paying attention to. Due to the unreasonable choice of parameters, it is easy to cause that the matching calculation of cage accidental movement protection device can not meet the standard requirements. From the current mobile car accident protection device of related research [2-10], for the car accident mobile protection device matching calculation and related parameters of the study is less, mobile car accident protection device matching calculation is verified UCMP device matching and applicability of the important work, this paper UCMP device type testing, Several key
parameter selection problems affecting the matching calculation of UCMP device are put forward, the causes of the problems are analyzed, and the effective solutions are put forward for the peers in the industry to discuss.

2. Composition of UCMP device
There are many kinds of UCMP devices. The most common UCMP devices are composed of detection subsystem, stop subsystem and self-monitoring subsystem. There are also UCMP devices composed of detection subsystem and stop subsystem (such as detection subsystem + wire rope brake); There is also a UCMP device composed of stop subsystem and self-monitoring subsystem, which can be applied to the drag and forced drive elevator with flat layer, re-flat layer and preparatory operation without opening the door. According to different structural types, the stopping subsystem is mainly divided into: tractor brake with redundancy, bidirectional wire rope brake, bidirectional safety clamp brake, wheel brake, rail clamp, etc. [11]

3. Basic principle, theoretical calculation and judgment principle of UCMP device

3.1. Basic principle
Door is not locked in layer and under the condition of the car door is not closed, due to the safe operation of the capsules by drive host or drive control system of any single component failure cause accident of capsules from stop moving, at this point, the capsules to run faster, when running at a certain distance, UCMP device of detection subsystem to the movement of the car accident, and the signal to stop, The car still accelerates. The stop subsystem in UCMP device starts to stop after receiving the stop signal, and the car begins to slow down when it reaches the maximum speed of accidental movement until the car is stopped. The main function of UCMP device is to detect unexpected car movement and reliably stop the car when the door is open.

3.2. The theoretical calculation.
The process that the cage moves unexpectedly to detect and trigger the protection device to stop the cage can be divided into three parts, that is, the stage of accidental movement, the stage of detection and response to trigger and the stage of stop.

In order to describe and calculate the detection, triggering and stopping processes of the cage accidental movement protection device, the following formulas are obtained according to the specific conditions of each movement process more accurately.

The formula for calculating the maximum speed $V$ of the car before deceleration is as follows:

$$v = \sqrt{2a_1s_1} + a_1(t_1 + t_2) + a_2t_3$$

(1)

The total distance of car accidental movement (the sum of acceleration distance and stopping distance) $S$ can be calculated by the following formula:

$$s = s_1 + (t_1 + t_2 + t_3)\sqrt{2a_1s_1} + \frac{1}{2}[a_1(t_1 + t_2)^2 + a_2t_3^2] +$$

$$a_1(t_1 + t_2)t_3 + \frac{v^2}{2a_3}$$

(2)

Where, $a_1$ is the acceleration assumed to be achieved by the traction drive elevator car under the condition of electrical failure caused by the internal control device, which is $2.5 \text{ m/s}^2$; $s_1$ is the maximum distance m of the cage away from the floor station when unexpected movement is detected; $t_3$ is the maximum response time of detection subsystem expected by the applicant unit (the time is a combination of response time of flat layer sensor and detection circuit, etc.) s; $a_2$ is the natural acceleration of the traction elevator given by the stop subsystem report, and the measured or calculated value $\text{m/s}^2$ of each working condition is taken. $t_2$ is the maximum response time of the triggering device applied by the applicant unit (considering that the response time of the brake contactor is approximately equal to that of the main contactor) s; $t_3$ is the maximum response time s of stop.
subsystem given in the stop subsystem report; \( a_3 \) is the average deceleration or theoretical calculation value m/s\(^2\) given in the stop subsystem report.

The purpose of stopping distance calculation at the test speed of the cage accidental movement protection device is to measure whether the stopping force of the stopping component has decreased to an unacceptable level with the same load and initial speed.

The following formula can be obtained according to the stopping process of the elevator cage accidental movement protection device at the test speed:

\[
s_2 = v_4(t_2 + t_3) + \frac{1}{2}a_2t_3^2 + \frac{v_5^2}{2a_3}
\]

\[
v_5 = v_4 + a_2t_3
\]

Where, \( v_4 \) is the test speed m/s set by the applicant unit; \( v_5 \) is the maximum speed m/s of the cage in \( t_3 \) time at the test speed. \( s_2 \) is the stopping distance m at the test speed.

3.3. Decision Principles
Combined with the above formula, the conditions for judging whether \( V \) and \( S \) meet the test basis are:

\[
v \leq v_0 \text{ and } s \leq s_0
\]

Where: \( v_0 \) is the expected maximum speed m/s before car deceleration given in the type test report of stop subsystem; \( s_0 \) is the maximum allowed total distance of accidental cage movement, which is 1.2m.

4. Unexpected distance movement of the car was detected
Common UCMP device detection subsystem is composed of a position sensor and the signal processing unit, the distance detection subsystem to mobile car accident \( s_1 \) is equal to half the length of the magnetic separation plate minus half of photoelectric switch distance from top to bottom, so the magnetic separation plate installation size decided to mobile car accident protection device test capsules accidentally moves the detection distance of the value. However, in the existing inspection code, there is no inspection requirement for the position and distance of the photoelectric switch installed on the car roof.

If the distance between the two photoelectric switches in the middle becomes larger, the value \( s_1 \) of the accidental movement distance of the car detected by UCMP device becomes smaller. It is easy to detect even the slight movement in the car and trigger the misoperation fault of stop. On the other hand, if the distance between the two middle photoelectric switches becomes smaller, the value \( s_1 \) of the accidental movement distance detected by UCMP device increases, which undoubtedly increases the total distance value of the cage movement. According to Formula (2), the total distance value of the cage movement may exceed the standard requirements [12]

To solve this problem, according to the requirements of GB7588-2003 "Safety Code for Elevator Manufacturing and Installation" (including amendment No. 1), that is, the maximum distance of the car accidental movement is 1.2m. Suggestion: Manufacturing unit should be required to provide installation drawings of photoelectric switch and magnetic separator plate, and add an item of inspection of installation distance of photoelectric switch to the existing inspection rules to ensure that the cage detects unexpected movement value within the range applied by the enterprise.

5. The response time of UCMP device
The response time of UCMP device is mainly composed of three parts: response time \( t_1 \) of detection subsystem, response time \( t_2 \) of trigger device and response time \( t_3 \) of stop subsystem. The response time \( t_1 \) of the detection subsystem is the sum of the response time of the position sensor and the signal processing unit. The response time \( t_1 \) of the common detection subsystem is less than or equal to 30ms. Common trigger device generally is the contactor, contactor and brand power as a result of the
enterprises to choose, there may be the actual use of the response time of the contactor than apply for matching calculation contactor when response time is big, this kind of circumstance, can meet the requirements when matching calculation, but the practical application, due to the large response time to choose, It is possible to exceed the standard requirements under bad conditions.

The response time of the stop subsystem is generally determined by the manufacturing unit when designing the product. According to Equation (2), if the response time of the stop subsystem is too large, the total distance of the cage's accidental movement may not exceed 1.2m. To solve this problem, it is suggested that the manufacturer should choose the contactor with smaller response time, and leave some allowance for the matching calculation. Such as selection of contactor response time is 25 ms, in matching calculation can be applied for contactor response time less than or equal to 40 ms, can through the calculation of matching sex already so, meet the standard requirements, but also can avoid d may also replace other contactor, its response time may be higher than the matching calculation of the contact response time. The manufacturers of stop subsystem should optimize the design and produce stop subsystem with small response time. In order to meet the requirement that the total distance of car accidental movement is not more than 1.2m, the response time of stop subsystem should be controlled within 300ms.

6. The expected maximum stopping distance of the car
Stop distance refers to the distance that the car decelerates from the beginning to the complete stop in the stop process of stop subsystem (stop component). For a new stop subsystem, its braking performance should be the best at the beginning, but with the use time is too long, the number of braking increases, the braking force decreases correspondingly, the braking deceleration also decreases, and the stop distance becomes longer. If the stopping distance is too long, it may exceed the standard requirements at a certain time node according to Equation (2). Therefore, it is necessary to select and determine the expected maximum cage stop distance in UCMP calculation. At present, different manufacturing units choose and determine the method is not consistent, some use the way of minimum deceleration to determine; Some use the maximum stopping distance; There are references to actual test data and other situations.

In view of this situation, it is suggested to adopt the parameter of maximum cage stopping distance uniformly according to the requirements of GB7588-2003 Safety Code for Elevator Manufacturing and Installation (including Amendment No. 1), that is, the maximum total distance of cage accidental movement is 1.2m, so it can be seen that the calculation of matching is determined by distance at last. Therefore, it is suggested that manufacturing unit design stop subsystem, according to Equations (1) ~ (4), select basic parameters according to the worst conditions to get the total distance of cage movement before deceleration \( s_1 + s_2 + s_3 \), and then subtract the total distance before deceleration \( s_1 + s_2 + s_3 \) from 1.2m, which is the maximum stop distance of cage accidental movement operation. The minimum stop deceleration speed can be calculated by dividing the maximum speed \( v \) squared before the car deceleration by 2 times the maximum stop distance.

7. Conclusion
This paper introduces the structure and principle of UCMP device matching calculation, and gives the matching calculation formula and judgment principle of UCMP device. Aiming at the problem that the synthetic calculation can not meet the requirements due to the unreasonable parameter selection in the matching calculation of UCMP device, the influence of several key parameters on the matching calculation is analyzed, and several feasible schemes for parameter selection are put forward for reference in the industry.

After analysis, it is concluded that: Should optimize the product design, manufacturing units shall, in accordance with the standard requirements, in the distance detection subsystem, contactor, response time, to stop subsystem, expected response time capsules the choosing key parameters such as maximum stopping distance, full consideration, the choice of key parameters, to guarantee a certain allowance, easy to use, also want to consider to no more than standards set by the threshold.
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