ABSTRACT: Balance coefficient is one of the most important properties of traction type elevator. The value of balance coefficient not only affects the comfort when passengers take the elevator, but also determines the service life of the elevator, which makes it of great significance to set a proper value of balance coefficient when the elevator is assembled. This article briefly describes the definition of balance coefficient and introduces some widely used approaches of measuring balance coefficient. It discusses the basic principle of measuring approaches and analyses the pros and cons of each approach. Through measuring the balance coefficient, provide the recommending measures to hidden danger. Suggestions on daily maintenance is offered to the elevator maintenance unity. Fast approaches of measuring balance coefficient should be considered as the main development directions in the future.

KEYWORDS: Traction type elevator; Balance coefficient; Measuring approach.

1 GENERAL INSTRUCTIONS

Many high buildings spring up with urbanization at present, and the use of elevators become more and more common in modern society, which makes various kinds of elevator accidents follow. An elevator malfunctioned in a hotel last month in Hubei province. 14 passengers were trapped in the elevator more than one hour and they called for help. Fortunately, they were rescued successfully and no one was hurt. Some specialists investigated and analyzed this accident subsequently, and the main reason was that the use unit added many marble slabs at the bottom of the elevator car after the elevator was assembled and checked, which made the car heavier. The maintenance unit responsible for this elevator did not adjust the weight of the counterweight. As a result, the balance coefficient was too low and the safety refinements activated, which made the car stop between two halls and caused much difficulty in the rescue work.

Nowadays, the security situation of elevator using receives more and more attention [1]. Elevators should be maintained every month, but as a reason of the careless work of maintenance unites and the lack of fund, so measuring balance coefficient will often be overlooked during the maintenance work. It is of great importance to measure balance coefficient and also necessary to adjust those unqualified elevators.

Consequently, in order to protect the people's lives and property safety, it is meaningful to measure balance coefficient and do some adjustment.

2 DEFINITION OF BALANCE COEFFICIENT

Traction drive is one of the most widely used driving modes in the elevator industry. The car and the counterweight hang on both sides of the traction sheave through hoist ropes. The schematic diagram of traction drive elevator is shown in Figure 1.

The gravity of the car and the counterweight presses the hoist ropes tightly in the groove of the traction sheave [2]. The relative motion between the groove and the hoist ropes provides breakout friction.
when the traction machine works, which drives car moving up and down in well along the pathway.

Balance coefficient can be better understood by the stress analysis. The stress analysis diagram of hoist ropes is shown in Figure 2.

Figure 2. Stress analysis diagram of hoist ropes.

In Figure 2, the tension on the counterweight side is $T_1$, and the tension on the car side is $T_2$. Setting the weight of counterweight $W$, the weight of car with no load $P$, the rated capacity of car $Q$, the weight of car when loaded $Q_A$, we can list these following equations.

$$T_1 = W$$

$$T_2 = P + Q_A$$

(1) (2)

In static state, the tension on the same rope is equal, so we can draw a conclusion that $T_1 = T_2$. Under this circumstance, the breakout friction provided by the hoist ropes in the groove of the traction sheave can do work without overcoming the weight of the car. So the traction force provided completely by the breakout friction drives car moving up and down in well and the traction machine works under the maximum efficiency.\(^\text{[13]}\).

In actual use, the weight of car varies when load changes, so $Q_A$ is a variation, but its value is in the range between the weight with no load and the weight with full load. Coefficient $q$ is introduced and its value is in the range of 0 to 1. Then we can list the following equation.

$$Q_A = P + qQ$$

(3)

Set the breakout friction $f$. The value of $f$ is the difference between the weight of counterweight and the weight of car, and the equation can be listed as follows.

$$f = W - Q_A = (P + Q_A) - (P + qQ) = Q_A - qQ$$

(4)

The counterweight and the car are in equilibrium under ideal condition. Coefficient $q$ is equal to zero under this circumstance and can be written by the following formula:

$$q = \frac{Q_A}{Q} = \frac{W - P}{Q}$$

(5)

where $Q_A$ = the weight of car when loaded; $Q$ = the rated capacity of car; $W$ = the weight of counterweight; $P$ = the weight of car with no load.

If the balance coefficient is too small, it will result in insufficient traction force and increase the burden of traction machine when the car is moving up with full load, causing the motor overheated while make the hoist ropes slip in the groove of the traction sheave when the car is moving down with full load. If the balance coefficient is too large, it will allow the car to carry more load, which will strengthen the traction relation and cause the car to hit ceiling.\(^\text{[4]}\).

Balance coefficient is one of the most significant properties of traction drive elevator. Utilize the counterweight to balance the weight of the car and ease the burden of traction machine when the car is moving up and down. The weight of counterweight is changeless while the weight of the car varies frequently when load changes, so setting a proper value to balance coefficient is crucial in order to make the working condition close to the ideal equilibrium situation. According to the specification for electric lifts, the balance coefficient of traction drive elevator should be in the range of 0.4 to 0.5.

3 APPROACHES TO MEASURE BALANCE COEFFICIENT

3.1 Weighing and calculation

Weigh the weight of counterweight $W$ and the weight of car with no load $P$, and the rated capacity of car $Q$ can be known on the rating plate, so we can calculate the balance coefficient $q$ according to formula (5). This approach is very simple, but it spends a lot of time in weighing. Generally we do not use it for its low efficiency.\(^\text{[5]}\).

3.2 Torque measuring

Firstly, measure the torque which balances the counterweight and the car. Secondly, calculate the difference between the counterweight and the weight of car with no load according to the moment equilibrium equation. Calculate balance coefficient $q$ according to the difference above and the rated capacity of car known on the rating plate finally. Measuring those data is very complex although calculation is very convenient. In order to complete the steps above, a number of experimental devices, such as, the torque sensor, traction sheave, strain gauge, computer, rotary union, connecting lines, should be prepared in the beginning and the connection of each wire should be checked carefully, it is very easy to make mistakes and we may get trouble during the measurement.

3.3 Handwheel testing

Load 35% weight of the rated capacity in the car, and then control the elevator, driving the car when it is at the same level with the counterweight. Turn off
the main power supply, and one person uses the brake release lever to release the brake when the other uses the handwheel to rotate the endless screw. The one that uses the handwheel should feel the torque of each side, and tells relevant personnel to increase load if the counterweight side is heavier while reduce load if the car side is heavier. Repeat the steps above until the torque to rotate the endless screw of each side is same. The ratio of the weight of the load in the car to the rated capacity is the balance coefficient right now.[6]

This approach works when other instruments are out of work or in the situation of power failure. But if the elevator is permanent magnet synchronous drive type or the controller cabinet has emergency electric operation with no handwheel, we should figure out another way.

3.4 Current measuring

According to the electric lifts-testing methods, concrete scheme as follows: load 30%, 40%, 45%, 50%, 60% weight of the rated capacity in the car individually, and drive the car up and down each time. When the car is at the same level with the counterweight, which is known as the center position, record the current value at the same time. Draw a current-capacity curve after recording and the intersection of upward curve and downward curve is the balance coefficient.

In order to confirm the center position, one person drives the car to the position where it is at the same level with the counterweight, and the other in the engine room makes a mark on the wirerope. Some elevator companies even own their own servers, and connect the server to the host in the control cabinet. It is very convenient to read the data of the center position on the screen of the server when the elevator is in the operation.

The measuring principle of this approach is that the value of current can reflect the weight of load. when the load of each side of the traction sheave is equal, which means the counterweight and the car are in equilibrium, the resistance of moving up and down is equal, so that the current value of each moving direction is equal. Drawing the curve is to find out the capacity with which the current value of each moving direction is equal. The advantage of this approach is that the measuring technology is mature, and it doesn’t need many professional measuring instruments. The load is standard weight which is accurate, and load is increased gradually. The whole measuring process is safe and the result is effective.

4 BALANCE COEFFICIENT MEASUREMENT

Last week, we evaluated the security of some elevators in a residential area in Hangzhou. Balance coefficient is a important test item besides some routine tests. Standard weights were leased from a elevator company, and each one weighed 25kg. The rated capacity is 1000kg, so 30%, 40%, 45%, 50%, 60% weight is 300kg, 400kg, 450kg, 500kg, 600kg, and the number of weights loaded in the car is 12, 16, 18, 20, 24 correspondingly. The diagram of carrying weights is shown in Figure 3.

![Figure 3. Diagram of carrying weights.](image)

Table 1. Current value at the center position.

<table>
<thead>
<tr>
<th>capacity(%)</th>
<th>direction of elevator travel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>upwards(A)</td>
</tr>
<tr>
<td>30</td>
<td>0.9</td>
</tr>
<tr>
<td>40</td>
<td>3.6</td>
</tr>
<tr>
<td>45</td>
<td>4.8</td>
</tr>
<tr>
<td>50</td>
<td>6.3</td>
</tr>
<tr>
<td>60</td>
<td>7.5</td>
</tr>
</tbody>
</table>

According to the data recorded in Table 1, the diagram of current-capacity curve is shown in Figure 4. In Fig.4, dotted line represents the current when the car moves upwards and dot dash line represents the current when the car moves downwards.

![Figure 4. Diagram of current-capacity curve.](image)
In Fig.4, we can see the horizontal coordinate of the intersection of upward curve and downward curve is 37%. The balance coefficient is small and doesn’t conform to the national standard. The elevator needs some adjustment.

5 ADJUSTMENT PROGRAMME

According to formula (5), the difference between the weight of the car and the weight of the counterweight is small, so we infer that the car is over decorated, as a result, the weight of the car with no load $P$ is increased so that the balance coefficient is small.

We suggest that the maintenance unit increase some counterweights or remove some trim parts, but it is more convenient to increase counterweight. In Fig.4, the horizontal coordinate of the intersection is before 40%, which means it takes more power to drive the car up. We can calculate that the weight of counterweight should be 400kg~500kg heavier than the weight of the car with no load according to formula (5) if the balance coefficient is in the range of 0.4 to 0.5. Now the balance coefficient is 0.37, which means the weight of counterweight is 370kg heavier than the weight of the car with no load according to formula (5), and 30~130kg should be increased to the weight of counterweight. As is told all above, 1~2 counterweights should be loaded to the counterweight side as a reason of one standard counterweight is 50kg generally.

6 CONCLUSION AND EXPECTATION

This paper summarizes the physical significance of balance coefficient from the perspective of theory and practice. The set of balance coefficient is to use counterweight to balance to weight of the car as far as possible so that the traction force provided by electric energy can control the car moving up and down completely without overcoming the force of the car.

Through this study and experiment, we can see the balance coefficient measurement is lack in the daily maintenance. The research on traction force and balance coefficient is propitious to daily management and control, and helps to reduce the occurrence of elevator accidents. Suggestions is made that balance coefficient measurement must be added into daily maintenance, especially for those elevators which is used over five years. Approaches of fast measuring balance coefficient and relevant measuring instruments are expected in the future.

REFERENCES