Research on the change of traction force of elevator after decoration

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Abstract. As a kind of vertical transportation, elevator has been widely used in people's life and production, and people have higher and higher requirements for elevators. In addition to safety and comfort, they also need to be beautiful, especially in shopping malls, hotels, office buildings and other places. In order to make the elevator beautiful, many elevator users will decorate the elevator car. However, the decoration company is only from the perspective of decoration, only responsible for the beauty of decoration, does not consider the safety performance of the elevator, and does not have professional knowledge of elevator. After the car is decorated, the decoration materials increase the weight of the elevator and the traction force of the elevator will change, which may seriously threaten the safe operation of the elevator, leading to the accident of car sliding and even squatting. Therefore, the elevator users should pay attention to the decoration, it is best to use light materials to reduce the weight added due to decoration as much as possible. After finishing the decoration of the car, the maintenance unit shall carry out relevant tests to ensure the safety of the elevator. This paper studies the change of traction force after elevator decoration, and puts forward some suggestions for reference.

1. Introduction
With the rapid development of the city and the increasing population, as a vertical transportation tool, elevator has been widely used in people's life and production [1]. People have higher and higher requirements for elevators. In addition to safety and comfort, they also need to be beautiful, especially in shopping malls, hotels, office buildings and other places [2]. Therefore, the elevator users sometimes hire decoration companies to carry out secondary decoration of the car. For example, marble is laid on the car floor, and glass mirrors are installed on the inner wall of the car [3]. However, the decoration company is only from the perspective of decoration, only responsible for the beauty of decoration, does not consider the safety performance of the elevator, and does not have professional knowledge of elevator [4]. In fact, although these decoration materials look humble, but the actual weight is very large. For example, if four marble floors and three glass mirrors are installed in the car, the actual weight can reach 200-500 kg. This is very likely to have a serious impact on the safe operation of the elevator [5]. Therefore, this paper studies the change of traction force after elevator decoration.
2. Calculation of traction force

It is necessary for the traction force to meet the traction condition to ensure the safety and reliability of traction drive [6]. According to 9.3 of national standard GB 7588-2003 Safety rules for the construction and installation of lifts, wire rope traction shall meet the following three conditions [7]:

(1) When the car is loaded to 125% of the rated load, it shall be kept flat without slipping.

(2) It must be ensured that in any emergency braking state, no matter whether the car is empty or full load, the deceleration value cannot exceed the deceleration value when the buffer (including the deceleration buffer) acts.

(3) When the counterweight is pressed on the buffer and the traction machine rotates in the upward direction of the elevator, it shall be impossible to lift the no-load car [8].

Appendix M of GB7588-2003 suggests that the following formulas should be used for the calculation of traction force:

\[
T_1 / T_2 \leq e^{\theta} \quad \text{Used for car loading and emergency braking}
\]

\[
T_1 / T_2 \geq e^{\theta} \quad \text{Used for car detention condition (i.e. counterweight is pressed on buffer and traction machine rotates upward)}
\]

In the formula: \( f \) is the equivalent friction coefficient; \( \theta \) is the wrap angle of the wire rope on the rope pulley; \( T_1 \), \( T_2 \) is the pulling force in the traction rope on both sides of the traction wheel; \( e \) is the base of natural logarithm.

It is assumed that the main parameters of an elevator are shown in Table 1 (regardless of compensation rope and traveling cable).

| Parameter name                             | Code | Parameter name                             | Code |
|--------------------------------------------|------|--------------------------------------------|------|
| Car weight                                 | \( P \) | Ratio of traction wire rope                | \( r \) |
| Rated load                                 | \( Q \) | Acceleration of gravity                    | \( g \) |
| Equilibrium coefficient                    | \( k \) | Car braking deceleration                   | \( a \) |
| Counterweight mass                         | \( W \) | Car loading condition                      | \( f_1 \) |
| Quality of traction wire rope              | \( W' \) | Car detention condition                    | \( f_2 \) |
| Wrapping angle of wire rope on rope pulley | \( \theta \) | Emergency braking condition                | \( f_3 \) |

The traction force calculation and check of the elevator shown in Table 1 are as follows [9]:

(1) Traction check of car loading condition (calculated according to 125% of rated load weight of car at the lowest floor station)

\[
\begin{align*}
T_1 &= \frac{P + 1.25Q + W'}{r} \times g \\
T_2 &= \frac{P + kQ}{r} \times g
\end{align*}
\]

Check: the car loading conditions should meet the requirement \( T_1 / T_2 \leq e^{\theta} \), that is, the traction wire rope does not slip on the traction wheel.

(2) Traction force check under emergency braking condition (calculated according to the condition of empty car on the top floor)
\begin{align*}
\begin{cases}
T_1 &= \frac{(P + kQ) \times (g + a) + W \times (g + a \times r)}{r} \\
T_2 &= \frac{P \times (g - a)}{r}
\end{cases}
\end{align*}

(2)

Check: under the emergency stop condition, when the no-load car is located at the highest floor station, it shall be able to meet the requirement $T_1 / T_2 \leq e^{f \theta}$, that is, the traction wire rope shall not slip on the traction wheel.

(3) Check the traction force under the condition of car detention (calculated according to the condition that the car is empty and the counterweight is pressed on the buffer)

\begin{align*}
\begin{cases}
T_1 &= \frac{P}{r} \times g \\
T_2 &= \frac{W}{r} \times g
\end{cases}
\end{align*}

(3)

Check: under the condition of car detention, when the car is empty and the counterweight is pressed on the buffer, it should meet the requirements $T_1 / T_2 \geq e^{f \theta}$, that is, the traction wire rope can slide on the traction wheel.

3. Analysis on the change of traction force of elevator after decoration

The self-weight of the car increases after the second decoration, in this case, the calculation of the traction force is as follows:

(1) Traction force check of car loading condition

\begin{align*}
\begin{cases}
T_1 &= \frac{(P + G) + 1.25Q + W}{r} \times g \\
T_2 &= \frac{P + kQ}{r} \times g
\end{cases}
\end{align*}

(4)

It can be concluded that:

$$\frac{T_1}{T_2} = \frac{T_1 + \frac{G}{r} g}{T_2} = \frac{T_1}{T_2} + \frac{G}{P + kQ}$$

(5)

When $G = 0$, $T_1 / T_2 \leq e^{f \theta}$ As G increases gradually, this condition is no longer satisfied.

(2) Traction force check under emergency braking condition

\begin{align*}
\begin{cases}
T_1' &= \frac{(P + kQ) \times (g + a) + W \times (g + a \times r)}{r} \\
T_2' &= \frac{(P + G) \times (g - a)}{r}
\end{cases}
\end{align*}

(6)

It can be concluded that:

$T_1' / T_2' < T_1 / T_2 \leq e^{f \theta}$, that is to meet the conditions.

(3) Check of traction force under car detention condition
\[
\begin{align*}
T'_1 &= \frac{P + G}{r} \times g \\
T'_2 &= \frac{W'}{r} \times g
\end{align*}
\]  

(7)

It can be concluded that:

\[
\frac{T'_1}{T'_2} - \frac{T_1}{T_2} = \frac{G}{W'} > 0
\]

(8)

It can be seen that if the self-weight of the car increases after decoration, the traction force check still meets the condition under the emergency braking condition and the car detention condition, but the traction force check may not meet the condition under the car loading condition [10]. When the car is fully loaded, the wire rope may slip in the rope groove of the traction wheel, that is, the car may slip or even squat due to insufficient traction force [11].

4. Conclusion

People have higher and higher requirements for elevators, in addition to safety and comfort, they also need to be beautiful, especially in shopping malls, hotels, office buildings and other places [12]. In order to make the elevator beautiful, many elevator users will decorate the elevator car. However, the decoration company is only from the perspective of decoration, only responsible for the beauty of decoration, does not consider the safety performance of the elevator, and does not have professional knowledge of elevator [13]. After the car is decorated, the decoration materials increase the weight of the elevator and the traction force of the elevator will change, which may seriously threaten the safe operation of the elevator, leading to the accident of car sliding and even squatting [14]. Therefore, the elevator users should pay attention to the following points when decorating the car:

1. It is better for users to put forward their own decoration requirements when ordering elevators from manufacturers, so as to leave room for the next decoration when designing elevators.

2. When the car is decorated, it is best to use light materials to reduce the weight added due to decoration as much as possible.

3. After finishing the decoration of the car, the maintenance unit shall carry out relevant tests to ensure the safety of the elevator.

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