Research on the Risks Brought by Elevator Decoration

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Abstract. With the development of economy and the continuous improvement of living standards, people have higher and higher requirements for elevator comfort and aesthetics, and many users decorate the elevator luxuriously, but this practice often does not go through the strict design and calculation of the elevator manufacturing unit, which brings great safety risks to the elevator. Starting from the relevant requirements of the national standard, this paper analyzes the compliance of elevator decoration materials, calculates the influence of elevator car decoration weight on the traction capacity of the elevator under loading conditions, braking conditions and detention conditions, and studies the damage of excessive decoration of the elevator to the elevator safety device, and proposes that the strict control of the decoration weight of the elevator car is very important to the safety of the elevator. The research results of this paper can guide the reasonable decoration construction of elevators and provide reference for the work of relevant inspection agencies.

Keywords: elevator; decoration; safety; risk

1 Introduction

In November 2014, in a residential building in Guiyang City, the elevator suddenly slipped out of control, and 12 people were trapped. The accident investigation found that the main reason for the loss of control of the elevator was that the car was laid with marble floor tiles, which was seriously overweight, resulting in the lack of traction capacity of the elevator.

The scene of excessive decoration of elevators is mainly concentrated in high-end hotels, office buildings, commercial and residential buildings, residential areas[1], etc.,and the decorative materials are mostly marble and ceramics[2][3], etc., but behind the luxury decoration of elevators there are extremely serious safety hazards. The main hidden danger of excessive decoration of the elevator is overweight[4], which brings two hidden dangers: first, the decoration material is too heavy, and the weight of the car increases, which affects the load capacity of the elevator; Second, it affects the safety performance of the elevator and changes the traction capacity of the elevator, which may lead to the failure of the elevator protection device[5].

In view of the potential safety hazards caused by excessive decoration of elevators, this paper studies the relevant causes and countermeasures. On the one hand, the problem of elevator car decoration materials is studied, and on the other hand, according to the relevant requirements of national standards, the influence of elevator car decoration weight on the traction capacity

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of the elevator under loading conditions, braking conditions and detention conditions is calculated, and the hazards of excessive decoration are discussed based on the calculation results and the scope of application of safety devices in elevator design documents.

2 Standard Basis

GB 7588-2003 Safety rules for the construction and installation of lift (hereinafter referred to as "7588") makes the following series of provisions:

8.3.2.2 Glass car walls shall meet the pendulum test requirements of 7588 Annex J.

8.3.2.3 The fixed parts of the glass car wall shall ensure that the glass will not slide out even if the glass sinks.

8.3.3 The walls, floor and roof of the elevator car shall not be made of materials which are flammable or may be hazardous due to the generation of harmful or large quantities of gases and fumes.

Annex F Safety components, type test certification procedures.

Annex M Traction force calculation.

On December 14, 2020, The State Administration for Market Regulation issued GB/T 7588.1-2020 "Safety rules for the construction and installation of lift - Part I: Passenger and Goods passenger lifts" (hereinafter referred to as "7588.1")[6], the new version of the standard has made more detailed requirements for the terms.

5.4.4.2 More detailed requirements are made on the combustion performance of materials: a) Car floor: C-S2; b) Car wall and door: C-S2, d1 ; c) Car ceiling: C-S2, d0.

We launch an analysis according to several aspects of the standard requirements.

3 Decoration Materials

Usually in the lift car decoration will use glass products, wood materials. The relevant requirements of glass lift car wall in the standard should also be extended to the glass decoration of the car. In the process of operation, the glass breakage caused by the sliding vibration will also cause harm to passengers[7]. Especially in the car safety gear gear action or hit the top, squatting accident, because the strength of ordinary glass can not fight against a certain impact, which is more prone to damage and easily cause secondary injuries[8]. For example, when a passenger elevator was being repaired and maintained in 2008, the safety gear action occurred after the elevator was hit to the top. As ordinary transparent glass was used in the suspended ceiling of the car, the glass was broken and fell down, injuring the head of a maintenance staff, resulting in the occurrence of injury accident.

As to woodiness decorate material, because joinery board holds screw force good, and it has the characteristic such as qualitative firm, high intensity,sound absorption, adiabatic. The structure of MDF is more uniform than natural wood, and it also avoids problems such as decay and insect decay. At the same time, it has little expansion and contraction, and is easy to

process. The surface of the board is smooth, and it is easy to stick various finishes. Lift cars are usually decorated with Blockboard and battenboards or MDF. According to the Blockboard and battenboards (GB/T 5849-2016) and Medium Density Fiberboard (GB/T 11718-2009), Blockboard and battenboards or MDF belong to wood products and may be flammable materials without fire retarding treatment. The same decoration may be used to acrylic products, but also in the absence of flame-retardant treatment is also flammable, and do not have self-extinguishing. Acrylic products used in the ceiling or wall, combustion will also produce dripping.

At the same time, 5.4.9.1 in 7588.1 clearly requires that the limited area of ventilation holes at the upper and lower parts of the car shall not be less than 1% of the effective area of the car, which may cause the ventilation holes of the car to be blocked in the decoration process, leading to non-compliance with the requirements in the standard.

4 Analysis of stressed parts

According to the special Letter [2019] No. 64 (hereinafter referred to as No. 64) of The State Administration for Market Supervision, the change of the elevator car weight(except the reserved decorative weight of the manufacturer or the cumulative increase/decrease of no more than 5% of the rated load weight) is for renovation construction. It can be seen that the change of elevator car weight caused by elevator decoration will have a great impact on the performance and safety of the elevator[9]. We do not analyze and calculate the case of "definite reserved decorative weight of manufacturing unit".

In the actual construction, the condition of "increase/decrease does not exceed 5% of the rated load except" is difficult to control because the weight of decoration material, so the condition of “5% more than the rated load may often happen. For the time being, we do not consider whether this situation is not in accordance with the provisions of No. 64. We only analyze and calculate the influence of the quality change of the car caused by decoration on the elevator safety[10].

4.1 Calculation of drag

Taking a common elevator in a business building as an example, the parameters are shown in Table 1.

Table 1. Parameters of elevator traction system

Parameter name	Parameters of the code	Unit	Parameter value
Elevator car wight	P	kg	1600
Rated elevator speed	V	m/s	2.5
Rated lift capacity	Q	kg	1600
Elevator balance factor	k	-	0.49
Lift height	H	m	98.6
Ratio of tow wire rope	r	-	1

Number of wire rope	n1	-	7
Weight per unit length of wire rope	-	kg/m	0.347
Number of compensating ropes	n2	-	2
Compensation rope weight per length	-	kg/m	2.23
Number of accompanying cables	n3	-	1
Weight per unit length of accompanying cable	-	kg/m	1.12
The upper wrapping Angle of wire rope rope wheel	α	degree	160
		rad	2.793
Drawwheel semicircular groove opening Angle	β	degree	45
		rad	0.786
Notch value of lower half circle groove of traction wheel	γ	degree	103
		rad	1.798
Elevator car decoration weight	QZ	kg	X

According to the above table, we can calculate several parameters first:

Coefficient of friction:

$$\mu_{loading}=0.1$$

$$\mu_{Stranded}=0.2$$

$$\mu_{Braking} =0.1/ (1+2.5/10) =0.085.$$

$$\frac{4\ (cos\frac{\gamma}{2}-sin\frac{\beta}{2})}{\pi-\beta-\gamma-sin\beta+sin\gamma}=1.94$$

Equivalent friction coefficient:

f_{load} = 0.1 * 1.94 = 0.194,

$$f_{Stranded}= 0.2 * 1.94 = 0.388,$$

$$f_{Braking} = 0.085 * 1.94 = 0.165.$$

Loading condition: $e^{f\alpha}=e^{0.194*2.793}=1.72$；

Stranded condition :$e^{f\alpha}=e^{0.388*2.793}=2.96$;

Emergency braking condition:$e^{f\alpha}=e^{0.165*2.793}=1.59$

Traction rope quality: W_1 =7*0.347*98.6=239.5kg;

Compensation ropes quality: W_2 =2*2.23*98.6=440kg;

Travelling cable quality: W_3 =1*1.18*98.6* (0.25+0.25) =55kg

Here, we ignore the friction in the well path. The acceleration of gravity g_n=9.8m/s^2, and the deceleration of the car during braking is calculated according to the minimum a=0.5m/s^2 as required by the standard. According to the formula(1)and(2):

$$T_1 = \frac{(P+Q+M_{CRcar}+MT_{RAV})(g_n \pm a)}{r} + \frac{M_{Comp}}{2r} g_n + M_{SRcar}(g_n \pm r \bullet a) + (-\frac{2m_{PTD}}{r} a)^{\text{I}}$$
$$\pm (m_{DP} \bullet r \bullet a)^{\text{II}} \pm [M_{SRcar} \bullet a(\frac{r^2-2r}{2}) \pm \sum_{i=1}^{r-1}(m_{Pcar} \bullet i_{Pcar} \bullet a)]^{\text{III}} \pm \frac{FR_{car}}{r} \quad (1)$$

$$T_2 = \frac{M_{cwt} \bullet (g_n \pm a)}{r} + \frac{M_{Comp}}{2r} g_n + M_{SRcwt} \bullet (g_n \pm r \bullet a) + \frac{M_{CRcwt}}{r}(g_n \pm a) + (-\frac{2m_{PTD}}{r} a)^{\text{IV}}$$
$$\pm (m_{DP} \bullet r \bullet a)^{\text{II}} \pm [M_{SRcwt} \bullet a(\frac{r^2-2r}{2}) \pm \sum_{i=1}^{r-1}(m_{Pcwt} \bullet i_{Pcwt} \bullet a)]^{\text{V}} \pm \frac{FR_{car}}{r} \quad (2)$$

(1) Car loading condition

When the car is at the bottom of the shaft and the weight of 125% of the rated load is in the car，Calculated to get:

$$\frac{T1}{T2} = \frac{(1600+X+1600*1.25+239.5)*9.8}{(1600+X+1600*0.49+440+55)*9.8} = 1.72$$

It can be calculated that X=-1545kg, that is, the car mass can not meet the standard requirements only when it is reduced by more than 1545kg, which will not occur in practice.

(2) Car emergency braking condition

The car is empty at the top of the shaft.In the braking case,Calculated to get:

$$\frac{T1}{T2} = \frac{(1600+X+1600*0.49)*(9.8-0.5)+239.5*(9.8-0.5)}{(1600+X+440+55)*(9.8+0.5)} = 1.59$$

It can be calculated that X=-879kg, that is, the car mass can be reduced by 879kg or more to meet the standard requirements, which will not occur in the actual situation.

(3) car detention condition

When the car is empty and fully compresses the buffer against weight,Calculated to get:

$$\frac{T1}{T2} = \frac{(1600+X++440+55)*9.8}{239.5*9.8} = 2.96$$

It can be calculated that X=-1387kg, that is, the car mass can be reduced more than 1387kg will not meet the standard requirements, this situation will not occur.

Thus, we can see that the elevator with the car mass of 1600kg as an example, after the weight of the car is reduced by more than 879kg, the traction force will not meet the standard. As for the condition that the elevator car quality increased due to the decoration, in order to guarantee the balance coefficient within the scope of the standard requirement, generally we solve this problem by increased counterweight, although it would not happen that traction do not conform to the requirements of the case, but it led to the steel wire rope tension, and enlarge the round tank pressure, resulting in the tractive rope and accelerate tractive sheave groove wear. If there is a large difference in the surface hardness of the wheel groove, the wear degree

of different parts will be inconsistent, presenting non-uniform wear, leading to periodic vibration and noise in the operation of the elevator.

4.2 Safety Gear

According to the determination of allowable mass of safety gear in Annex F3.2.4, 7588, the total energy that can be absorbed by safety gear is according to formula (3).In the formula，K is the energy absorbed by a safety gear body, h is the distance of free fall, gn is the acceleration of gravity, Q is the rated load, P is the quality of empty elevator car and parts supported by the car).

$$2K = (P + Q)\ gn \bullet h. \tag{3}$$

For the decorated elevator, it is obvious that when P changes, the total energy absorbed by the safety gear changes.

As shown in the safety gear commissioning Certificate 1 in Table 2, the safety gear is used for a single quality safety gear when the permitted mass (P+Q)=2100KG. If P changes, the safety gear should no longer be applied to the elevator.

Table 2 Safety gear commissioning Certificate 1

Applicable to elevator quality	Confirm the P+Q value	2100Kg

As shown in the safety gear commissioning record 2 in Table 3, the permitted mass (P+Q)=2201-2400kg, the rated load of the elevator is 1000KG, and the range of P is 1201-1400kg. We assume that the current P=1201KG, and the car decoration is more than 200KG, that is 20% of the rated load. The safety gears don't work either.

Table 3 Safety gear debugging record 2

Rated Speed 0.25-2.5m/s	Rated Load 2201-2400Kg

Therefore, after the elevator decoration, whether the car quality increases or decreases, there will be a high possibility that the safety gear is no longer applicable, but it is easy to be ignored in the construction and inspection time.

5 Conclusion

Among the maintenance, construction and inspection of elevator, elevator decoration is now in a gray area.The excessive decoration of the elevator has serious safety risks, which need to be highly valued by the people in the industry.

In order to solve this problem, the decoration materials of the elevator are discussed, and the traction force of the elevator under different working conditions is calculated according to the standard requirements, and the calculation results show that the increase of the decorative weight of the elevator car will affect the traction capacity and reduce the performance of the elevator installation device. Therefore, in the decoration construction process of the elevator, it is necessary to strictly follow the relevant national standards to control the decoration weight, and after accurate design and calculation.

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