Mechanical strength analysis of lift steel landing doors based on statistical methods

Shuai Kong¹,²,*, Zhangwei Ling¹,², Mulin Zheng¹,², Yinde Jin¹,² and Zhenchao Zhou¹

¹ Zhejiang Provincial Special Equipment Inspection and Research Institute, Hangzhou, China
² Key Laboratory of Special Equipment Safety Testing Technology of Zhejiang Province, Hangzhou, China

*Corresponding author e-mail: kongshuai@zjtj.org

Abstract. The landing doors are quite important to the safety of the passengers during waiting and using lifts. In order to know the safety situation of the lift landing doors after China’s new regulations issued, the type test results of 647 landing door samples are summarized and analysed, including thickness analysis, static strength test analysis and impact test analysis. The result shows that the maximum elastic deformation can be fitted to have proportional relationship with the applied force, and the protrusion clearance into well after impact test of 89% doors are below half of the given limit in regulations.

1. Introduction
The lifts are becoming more common and irreplaceable in our daily life, while the safety risk follows too. The lift landing door is the safety barrier of the passengers and the lift well. It is very important to avoid passengers falling down into the well. In the past several years, there were many lift accidents happened due to the weakness of landing doors in China. Therefore, the static strength and impact test are added in the No. 1 modification of China’s GB 7588 [1] and “Regulation for type test of lifts” [2]. Some type test institutes carried out amounts of supervisory tests of the existing lift landing doors before the new regulations applied, the results showed that only lower than 20% of existing landing doors could satisfy the meet of the new regulations, as well as most failures occurred as the lower block getting out of slot after the impact test. This is obviously the main cause of many lift landing door accidents.

After the new regulations are published and issued, the mechanical strength of landing doors is valued much more by the lift landing door manufacturers. However, what about the new performance of the doors following the new regulations? Depend on the accumulation of landing door type tests, a big amount of test results is summarized and analyzed, in order to obtain some safety situation and conclusion.

2. Tests and Results Naming Rule
647 lift landing door samples of distinctive types and models made by different manufacturers were type tested. In those samples, only 11 samples (about 1.7%) were made by glass material, the rest samples
were all made by steel material. In this paper, only the steel samples are taken in consideration, and they can represent the vast majority of the landing doors that are in actual usage in the future.

The 636 steel landing door samples were tested by static strength test, as well as impact test. First, the static strength test was carried out includes two different force levels: 300N and 1000N. The maximum elastic deformation (E) and maximum permanent deformation (P) were measured after every force applied. Second, the impact test was carried out by a pendulum to strike against the weakness of the door leaf. The protrusion clearance into the well after impact was measured.

Because the type test covers a range of landing door leaf widths, every sample contains two doors with different door leaf width, which are respectively namely narrow (N) and wide (W) in this paper. The abbreviation inner brackets in this section are used to name related data in next section, such as E300N, P1000W, etc.

3. Analysis

3.1. Thickness analysis

The thickness is clearly the most important indicator of strength. As shown in Figure 1, most landing doors are designed with the leaf thickness of 1.2mm and 1.5mm. According to the test results, samples with bigger than 1.2mm thickness were easier to pass the test, while samples with under 1.0mm thickness needed enough reinforcing rib support.

![Figure 1. The landing door leaf thickness distribution.](image)

3.2. Static strength test analysis

The static strength results and their relationship of the wide dimension doors is shown in Figure 2. It is clearly shown that the maximum deformation has strong correlation with the thickness, especially the maximum permanent deformation, shown in P300W-P300W and P1000W-P1000W. The maximum elastic deformation is proportional to the force level, as shown in E1000W-E300W. The maximum permanent deformation is messy than the maximum elastic deformation, as shown in P1000W-P300W. Their relationship can be fitted as equation (1) and (2). In the same way, the narrow dimension doors results can be fitted as equation (3) and (4).

\[
E_{1000W}=2.906 \times E_{300W} - 0.6271 \quad (1)
\]

\[
P_{1000W}=1.925 \times P_{300W} + 0.5526 \quad (2)
\]

\[
E_{1000N}=2.790 \times E_{300N} + 0.8572 \quad (3)
\]

\[
P_{1000N}=2.347 \times P_{300N} + 0.3015 \quad (4)
\]
3.3. Impact test analysis

According to the supervisory tests results of the existing doors before new regulations, most failures occurred while the impact test. However, great progress has been made according to those tests in this paper. The protrusion clearance into the well after impact test is most (89%) below 60mm, that is a half of the given limit in standard regulation. That indicates that most landing doors have a lot of margin to the standard. And it has no big difference between the narrow doors and the wide doors of the same model and structure. The relationship of protrusion clearance of narrow and wide doors can be fitted as equation (5). The equation shows that the clearance is little affected by the width of door leaf with the same height and model. The narrow doors could most likely pass the test if the wide doors passed already.

\[ \text{ImpactW} = 1.144 \times \text{ImpactN} + 3.685 \] (5)
4. Conclusion
The lift landing door is the safety barrier of the passengers and the lift wall. It is very important to avoid passengers falling down. The static strength and impact test are added in the No. 1 modification of China’s GB 7588 and “Regulation for type test of lifts”. After 636 type tests of steel landing doors, the following conclusions are obtained.

1. Most landing doors are designed with the leaf thickness of 1.2mm and 1.5mm, while doors under 1.0mm thickness needed enough reinforcing rib support.

2. The maximum deformation has strong correlation with the thickness in static strength test, the maximum elastic deformation can be fitted to have proportional relationship with the applied force.

3. The protrusion clearance after impact test of 89% doors are below half of the given limit in standard regulation, the wide doors test results could represent that of the narrow doors.

References
[1] GB 7588-2003+XG1-2015, Safety rules for the construction and installation of electric lifts, S.
[2] TSG T7007-2016, Regulation for type test of lifts, S.