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ESCALATOR STEP DISPLACEMENT'S ACCIDENT: FORENSIC ENGINEERING APPROACH

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Abstract

In Malaysia, escalator accidents caused injuries or fatalities. As a result, a forensic engineering technique was employed to look into the real causes of an escalator malfunction. There was escalator occurred in 2016, KL Sentral. The escalator accident in 2016. The escalator step displacement is the clearance of a step along the vertical and lateral axes. According to BS EN 115-2017, a step's clearance shall be measured. Step alignment of the escalator steps pass through the comb will be affected by step displacement that is outside of the permitted range, either the lateral or vertical direction that led to collision. The alignment of the escalator steps that moving through the comb will be hampered by step displacement that is more than the standard and it may result in a collision between the two parts on either the upper landing platform or lower landing platform. The impact from the collision of steps and combs may also injured escalator passengers. Hence, the clearance of the step in the vertical and lateral direction at any time. It is crucial to inspect and measure the step displacement parameter for both lateral and vertical step displacement. Improper installation of the step axle slot component on the step shaft; lateral step displacement is caused by clearance between a bush and stopper ring component, while vertical step displacement is caused by clearance between an axle slot and bush component. Prior, installation of those steps must be done carefully to avoid any clearance to prevent step displacement's accident occurred.

Keywords: Escalator, Steps Displacement, Lateral Step Displacement, Vertical Step Displacement.

1.0 INTRODUCTION

The statistic of accident from the year 2011 to 2015 as reported by the Department Occupational Safety and Health Malaysia indicated that 97% of the escalator accidents involved young children [1][2]. The unique approach of the forensic engineering investigation has been carried out to identify the real causes of the accidents in technical way of approach. This case study, focuses on the escalators or moving stairs which are facilities that are widely used nowadays in order to facilitate the movement of people from one level to another in shopping centers, commercial buildings, public facilities complexes and so on. To ensure, the safety of escalator usage, each escalator is designed, built and installed according to international recognized design codes. For most escalators in Malaysia, they are designed according to EN 115-1 code. Based on the provisions in EN 115-1 code [3], there is detailed requirement related to the installation of escalator steps. Step displacement is a parameter that needs to be aware. Step displacement refers to clearance or step mobility in the vertical and lateral directions, Figure 1 shows the direction of step movement that has vertical or lateral displacement. The measure of clearance or maneuverability of a step should be as specified in code [4]. It's stipulated that the lateral displacement of step or pallet out of their guiding system shall not exceed 4 mm at either side and 7 mm for the sum of clearances measured at both sides and the vertical displacement shall not exceed 4 mm for steps and pallets and 6 mm for belts. Step displacement that exceeds the standard, either in the lateral or vertical direction, will interfere

the alignment of the escalator steps while passing through the comb and can cause a collision between the two components. [Figure 1]

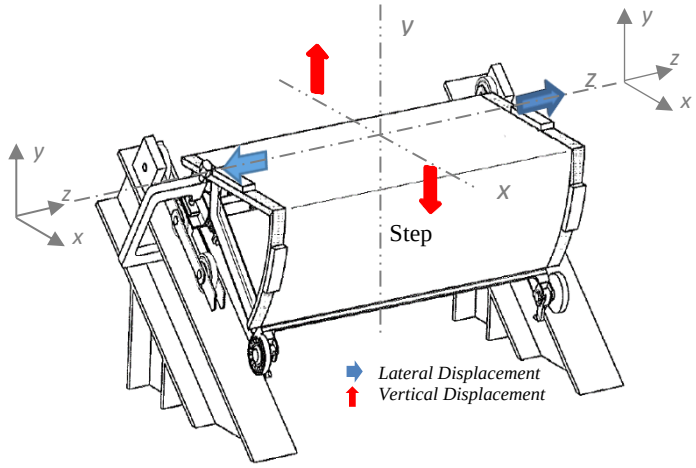

Figure 1: Direction of Vertical and Lateral Step Displacement Movement

2.0 METHODOLOGY

Forensic engineering investigation approach on the visual inspection on site of the accident was conducted onsite for KL Sentral escalator's accident scene focus on the escalator itself [5]. (Excluded behavior of the passenger using the machine) [6],[7],[8],[9]. A comprehensive inspection, observation, measurement and sampling for the vertical and lateral displacement steps were taken. The steps that involved in the incidents have been confiscated as evidence. Those items, will undergo forensic analysis in Forensic Engineering Lab (FEL, DOSH) for further investigation. Those steps were as such:

2.1 Causes of Step Displacement.

In general, Forensic engineering, in the context of investigating step displacement caused by clearance issues in the installation of the step axle slot on the step shaft, involves a systematic approach to analyzing and determining the root cause of the problem. [Figure 2]

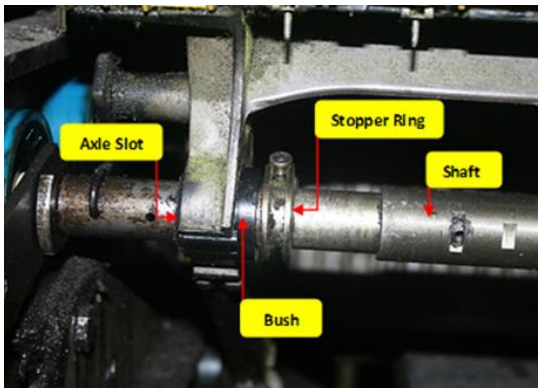

Figure 2: Axle Slot and Step Shaft Positioning

2.2 Lateral Step Displacement Parameters

Furthermore, performing a detailed investigation and forensic engineering on the measurement for lateral step displacement parameters according to code involves a systematic examination and analysis of the measurement process and data.[10] [Figure 3]

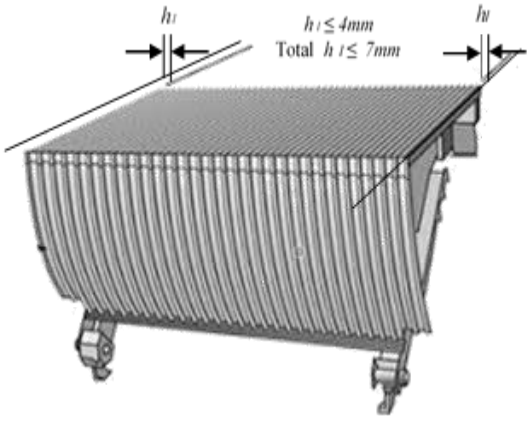

Figure 3: Measurement of Lateral Step Displacement *(hl)*

2.3 Vertical Step Displacement Parameter

In addition, forensic investigator also measured the vertical step according to the code for the vertical step displacement parameter. [Figure 4]

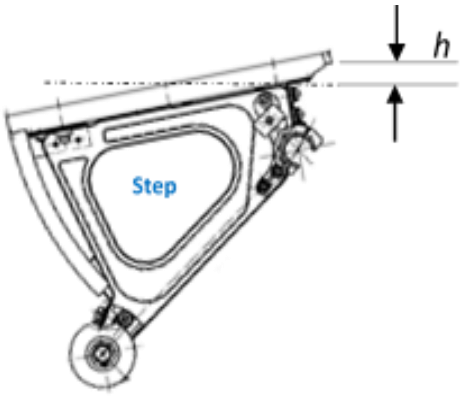

Figure 4: Measurement of Vertical Step Displacement (h)

3.0 RESULTS AND DISCUSSION

3.1 Cause of Step Displacement

The bush unit and stopper ring are important components in the installation of the step axle slot on the step shaft of an escalator. The position of these components on the step shaft has an impact on the step displacement parameter of the escalator step. Figure 5 illustrates that if there is clearance between the bush and stopper ring during installation, it can result in lateral step displacement. Lateral step displacement refers to the sideways movement of the escalator step. The greater the clearance between the bush and stopper ring, the larger the lateral step displacement will be. This can potentially cause alignment issues and affect the smooth operation of the escalator. On the other hand, Figure 6 demonstrates that clearance between the step axle slot and bush during installation can lead to vertical step displacement. Vertical step displacement refers to the up and down movement of the escalator step. If there is a significant clearance between the step axle slot and bush, it can cause the step to move vertically more than intended. This can also lead to operational problems and discomfort for passengers. To ensure proper functioning and safety of the escalator, it is important to minimize the clearance between the bush and stopper ring as well as the step axle slot and bush during installation. This will help to minimize both lateral and vertical step displacements, resulting in a smoother and more reliable escalator operation.[11]

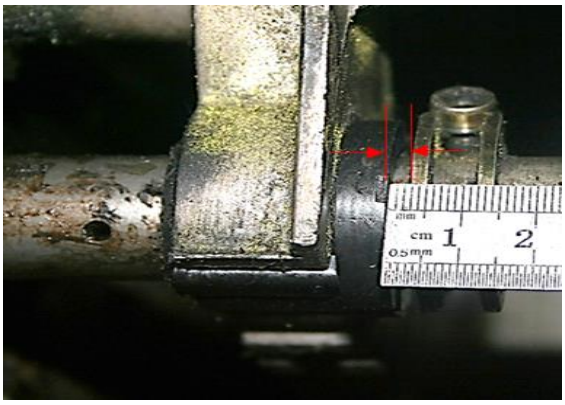

Figure 5: Bush and Stopper Ring Mounting Clearance

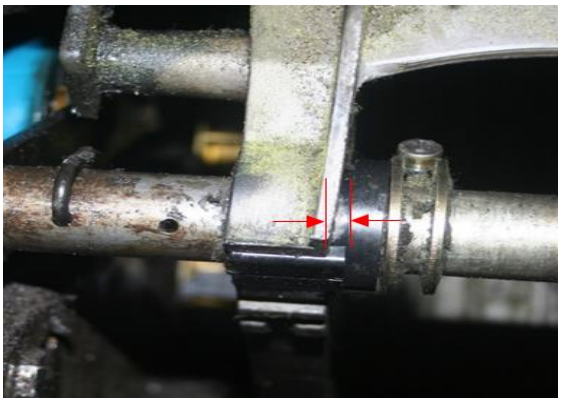

Figure 6: Axle Slot and Bush Mounting Clearance

3.2 Lateral Step Displacement Parameter

Figure 7 appears to illustrate the measurement of the lateral step displacement parameter (hl) as described in the statement. The purpose of this measurement is to ensure that steps do not deviate excessively from their intended path or guiding system. According to the given requirement, the lateral displacement of a step out of its guiding system should not exceed 4 mm on either side. This means that the step's movement to the left or right should not exceed 4 mm individually. Additionally, the sum of the clearances measured on both sides, which represents the total lateral displacement of the step, should not exceed 7 mm. In other words, if we measure the displacement on one side as hl1 and the displacement on the other side as hl2, the sum of hl1 and hl2 should not exceed 7 mm. These requirements are in place to ensure that steps remain within acceptable limits of deviation from their intended position within the guiding system, thus promoting safety and stability. [Figure 7]

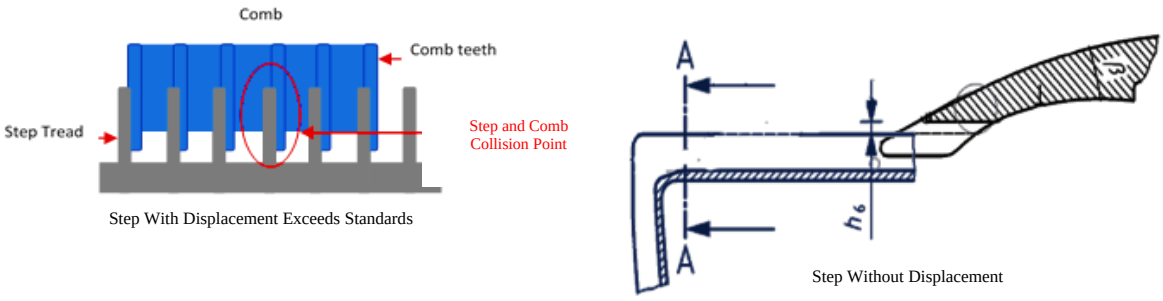

Figure 7: Collision Point Between Step with Lateral Displacement and Comb

3.3 Vertical Step Displacement Parameter

According to code stipulated that the vertical displacement shall not exceed 4 mm. Therefore, if the vertical step displacement (h), then the value (h) cannot exceed 4mm. [Figure 8]

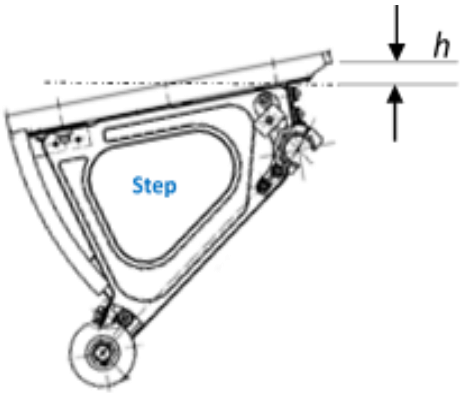

Figure 8: Measurement of Vertical Step Displacement (h)

A large vertical step displacement parameter (h) will indirectly reduce the clearance between the step and the comb (h6) which will then cause a collision between the two components during the step through the comb as shown in Figure 9.

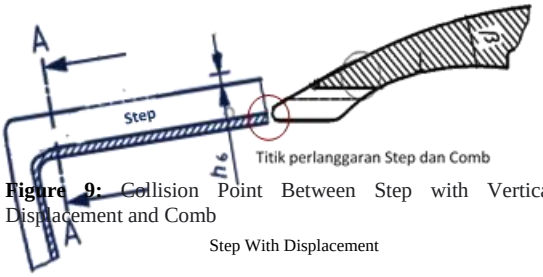

Figure 9: Collision Point Between Step with Vertical Displacement and Comb

3.4 Effect of Steps Displacement

Step units that have step displacement measurement parameters exceed the code will have the following effects. The effects including to the step thread and demarcation which caused the reduction of step width and depth web and severe fiction to comb teeth. [Figure 10, 11, 12, 13] [5]

Figure 10: Friction effect on step tread and demarcation line

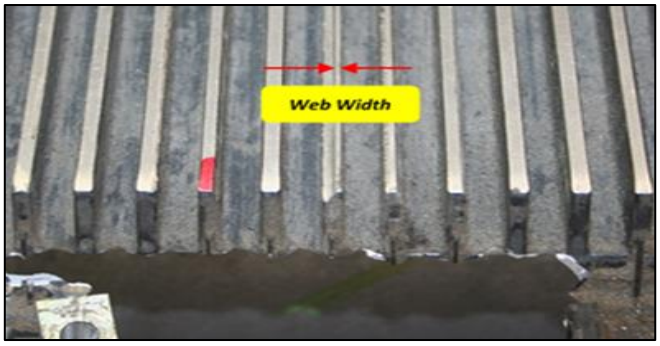

Figure 11: Reduction of step web width parameter

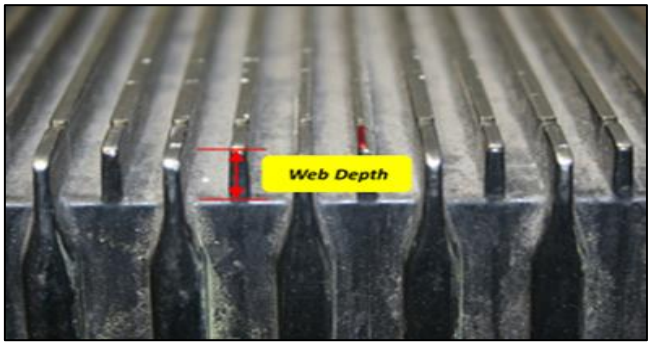

Figure 12: Reduction of step web depth parameter

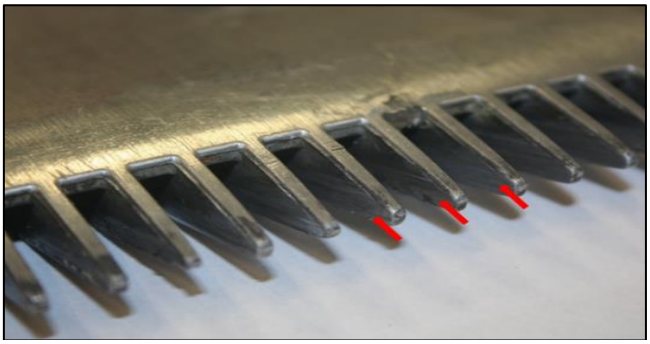

Figure 13: Friction effect on comb teeth

3.5 Limitation

Forensic Engineering Lab (FEL), Department Occupational Safety and Health Malaysia has limited of testing machines especially on the mechanical testing apparatus (Load Test and Tensile Test).

4.0 CONCLUSION

Hence, based on the forensic engineering investigation of the escalator accident in KL Sentral in 2016, it was determined that the misalignment of steps while passing through the comb was a major cause of the accident. This misalignment led to the step displacement parameter exceeding the code limits. Continuous friction between the step tread and comb teeth due to misalignment resulted in the reduction of step web width and web depth parameters. The lack of inspection and maintenance allowed for collisions between these components to occur. These collisions not only affected the operation of the escalator but also posed a risk to the users. To prevent such accidents, it is crucial to conduct periodic inspections of the entire step unit. These inspections can help identify any effects indicating step displacement. Measurements should be taken to determine whether the step displacement is within the code limits. If any step units are found to have step displacement exceeding the code, immediate maintenance and repair should be carried out. By performing regular inspections and promptly addressing any issues related to step displacement, escalator safety can be maintained, reducing the risk to users and ensuring proper operation of the escalator.

Acknowledgement

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