A Countermeasure to Reduce Secondary Impact Velocity and Rib Deflection Criterion of Longitudinal-Seat Passengers in Railway Collisions

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I. INTRODUCTION

Railway passengers are not usually provided with safety seat-belts, which means they can be thrown forward in the event of a frontal collision. Passengers sitting on longitudinal seats could be projected a significant distance and could collide, at high velocity, with the interior train structures. Based on sled tests simulated by using UK Railway Group Standards GM/RT2100, a previous study [1] applied acceleration pulses to passengers and found that the most severe injuries occurred to passengers seated in the second and third position, nearest to the bench-end partition. Other studies claim that a higher Secondary Impact Velocity (SIV) correlates positively with the more severe passenger injuries [2-3]. Therefore, reducing the SIV is vital in order to decrease the severity of injuries to passengers in general.

Numerical simulations are useful for obtaining effective case studies concerning the behaviour of passengers, by transferring and leaning them to the bench-end partition. In 2015, we proposed a numerical simulation method to reproduce sled tests for passengers seated at the third position from the bench-end partition [4]. In this method, although the Head Injury Criterion (HIC) was overestimated due to the vibration of the head acceleration, the error of the SIV was below 3%. In 2016, we highlighted the influence of distance from the bench-end partition and the input acceleration on the SIV for one passenger [5]. The present study uses this method to examine how the friction of the longitudinal seats and the presence of the handrail affect the behaviour of the passengers. The purpose of this study is to investigate the effect of reducing the SIV and the Rib Deflection Criterion (RDC) through use of the handrail, including two passengers.

II. METHODS

The numerical simulation allows us to investigate how handrails on longitudinal seats affect the SIV and RDC. In reference to previous studies, which were related to transverse [6] and longitudinal railway seats [4], the friction coefficients (μ) were 0.6 and 0.9, respectively. The present study considers a triangular acceleration pulse with a peak acceleration of 7 G (Fig. 1). Initially, the dummy models, which are called P1 and P2, were positioned as shown in Fig. 2. The average width of a Japanese longitudinal seat is approximately 460 mm, so three ES-2s cannot occupy the available space. The parameters are the sitting position of the front-back direction and the yawing. The case studies were implemented to yield a total of 84 different parametric combinations. The evaluation indexes were: P1's SIV; P1's RDC of the left side; and P2's RDC of the right side. The velocity of the head was considered the travel direction velocity.

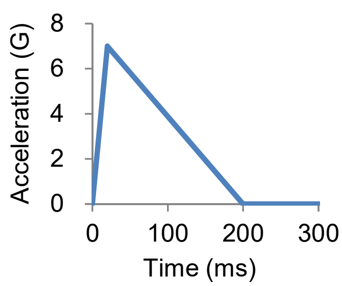

Fig. 1. Acceleration pulse.

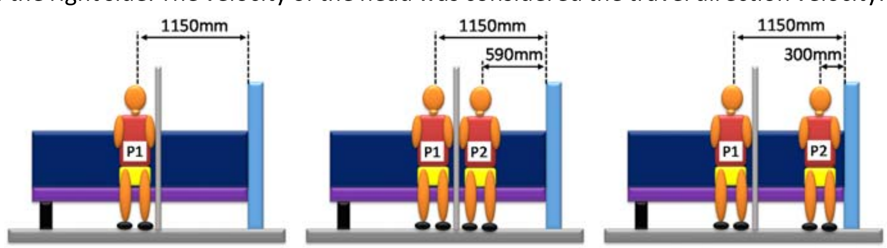

Fig. 2. Initial position of case study.

III. INITIAL FINDINGS

Figure 3 shows the relationship between the head velocity and the head displacement without the bench-end partition. It also includes the integration of the input acceleration (Delta V). The head velocities were higher than the Delta V for both μ. The maximum velocity in the case of μ = 0.9 was higher than that with μ = 0.6.

Figure 4 shows the head velocities with and without handrail. When μ = 0.6, the maximum velocity with the handrail was higher than that without it. When μ = 0.9, the maximum velocity with handrail was lower than that without handrail.

Figure 5 shows the postures of the dummy models at the secondary impact with or without handrail. Figure 6 shows the mean and the standard deviation of the SIV in the case studies. For one passenger, the SIV with handrail decreased remarkably. In the case of two passengers, the SIV with handrail showed almost no change.

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Figure 7 shows the mean and the standard deviation of the RDC in the case studies. For one passenger and two passengers, P1's RDC with handrail showed almost no change. In the case of two passengers, P2's RDC with handrail decreased remarkably.

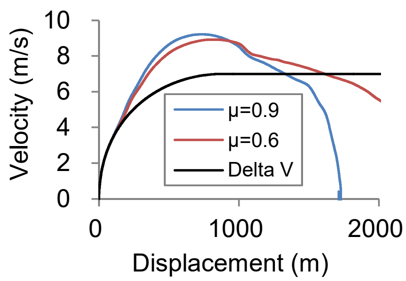
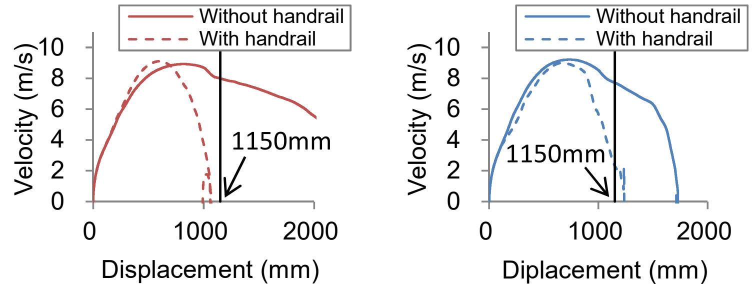
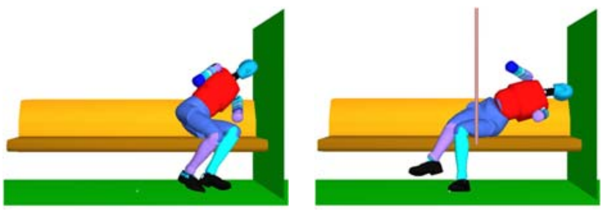


Fig. 3. Head velocity as a function of the displacement.



(A) $\mu = 0.6$ (B) $\mu = 0.9$

Fig. 4. Comparison of the head velocity with and without the handrail.



(A) Without handrail (B) With handrail

Fig. 5. Posture at the secondary impact.

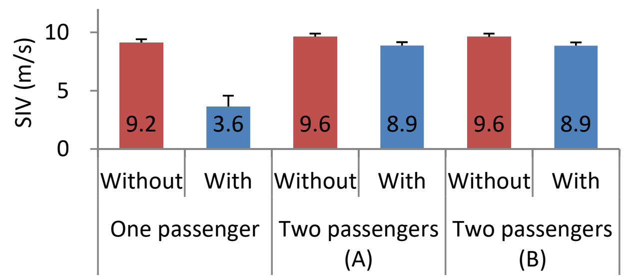


Fig. 6. Comparison of SIV.

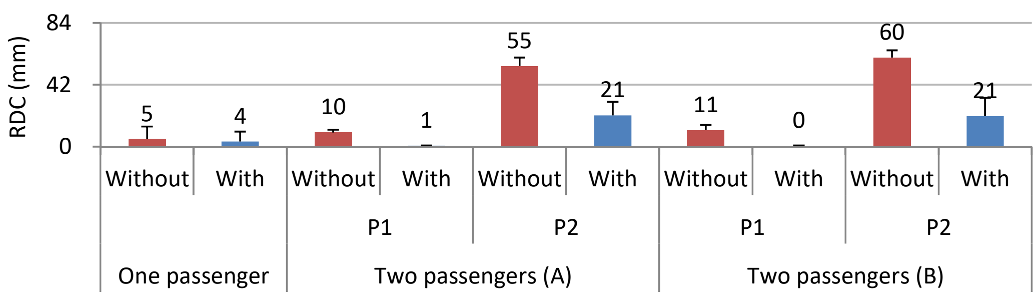


Fig. 7. Comparison of RDC.

IV. DISCUSSION

The reason why the head velocity was faster than the Delta V, as shown in Fig. 3, is the leaning behaviour of the dummy model. The SIV is the sum of Delta V and the velocity during the leaning. The head velocity became faster because the higher friction coefficient promoted the leaning effect.

When μ = 0.6 (Fig. 4), although the head velocity with handrail was higher than that without handrail at a displacement of approximately 500 mm, a secondary impact barely occurs during the displacement in the condition of the present study. When μ = 0.9, the reason why the head velocity with handrail is lower than the one without handrail is that the collision between the knee of the dummy model and the handrail promoted the leaning behaviour.

From these results it can be concluded that the handrail reduced the SIV in the case of one passenger. The head velocity with handrail in Fig. 4 decreased suddenly after a displacement of 1,000 mm. Since the initial distance between the dummy model and the partition was 1,150 mm, the handrail decreased the SIV effectively. The handrail also reduced the P2's RDC in the case of two passengers. The collision between the P1's left arm and the P2's right ribs caused high RDC values without the handrail. The P1's left arm did not collide with the P2´s with the handrail.

Although the maximum head velocity with handrail became higher in some cases, the handrail reduced the SIV and RDC under the conditions proposed in the present study.

V. REFERENCES

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