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Experimental Study on the Impact Load of Hybrid III 50th Male Dummy in Elevator Car

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Abstract. If the elevator breaks down during operation, it may lead to emergency braking. Emergency braking of the elevator may cause impact injury to personnel in the elevator car. In this paper, the injury degree of personnel under different working conditions is quantitatively analyzed by dummy test. The results show that within the allowable capacity of brake, safety gear and buffer, the stress and compression deformation of personnel in the lift car are within the allowable value in case of emergency braking.

1. Introduction

In case of emergency, the emergency braking of the safety protection device may cause injury to the personnel in the elevator car. Common safety protection devices involved in elevator emergency braking include brake, safety gear, buffer, etc. During emergency braking of elevator, it is difficult to quantitatively measure the impact of different emergency braking conditions and different postures of personnel in the elevator car on the impact load, and how much damage the personnel in the elevator car will suffer when hitting the buffer at a speed exceeding the allowable speed of the buffer. Therefore, using dummy impact load test to quantitatively measure the injury degree of personnel under different conditions is of great significance for the scientific design of elevator safety protection device.

The Hybrid III 50th percentile male dummy was developed by General Motors in 1976. It is used in aerospace, automobile, high-speed rail and other fields. It is the most widely used test dummy in the world so far. Ballo et al. [1] developed a new six axis load cell and applied it in the Hybrid III dummy frontal impact test to measure the acceleration and impact force at two different points of the dummy's head. Nouredine et al. [2] established the finite element model of Hybrid III crash test dummy for computer crash simulation. The results show that the reasonable accuracy obtained from the model is helpful to improve the crashworthiness simulation results when combined with other restraint system models. Hu et al. [3] developed an Improved Hybrid III six-year-old dummy model that can simulate and predict submarine navigation. Studies have shown that restraint system design variables may have an opposite impact on the risk of head and abdominal injuries. Kapoor et al. [4] used a Hybrid III three-year-old dummy to study the possibility of injury to children's forward and backward child restraint seats in vehicle frontal collision. The results show that the neck injury standard of the rear facing child dummy is significantly lower than that of the front facing child dummy, while the head injury standard is similar to that of the front facing child dummy. Dvorznak et al. [5] studied the effectiveness of the hybrid II 50th percentile dummy as an accurate substitute for wheelchair test pilots.



The results show that the improved test dummy underestimates the trunk dynamics during the release braking of the joystick. Li et al. [6] used the Hybrid III dummy to study the biomechanical response of the head when hit by different sticks. The results show that the harder and larger the rod, the higher the von Mises stress, contact force and intracranial pressure.

In this paper, the Hybrid III 50th percentile male dummy is used to simulate the injury degree of personnel under different working conditions of elevator emergency braking. The injury degree of personnel under different working conditions is analyzed by collecting the impact load and displacement of the dummy's upper neck, chest ribs and lumbar spine.

2. Dummy impact experiment procedure

The schematic diagram of sensor installation position for dummy is shown in Fig. 1. As shown in the figure, in order to study the stress of the upper neck and lumbar spine, force sensors are installed at these two places; In order to study the displacement of chest ribs, a displacement sensor is installed here.

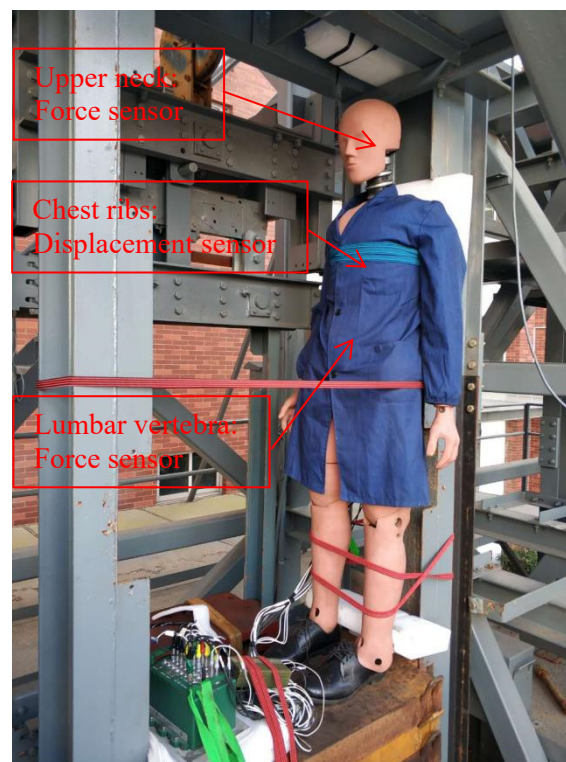


Figure 1. Schematic diagram of sensor installation position for dummy.

Four different working conditions are set in this experiment, namely no-load up brake braking, full load down brake braking, full load down safety gear braking and full load pier bottom braking. Three different safety protection devices, brake, safety gear and buffer, respectively participate in the emergency braking of the elevator. The braking conditions of no-load up brake and full load down brake are implemented on the real elevator test tower, and the braking conditions of full load down safety gear and pier bottom are implemented on the elevator test derrick. The rated lifting capacity of real elevator and test derrick simulated elevator is 1600kg and the rated speed is 1m/s. The dummy adopts three different postures: standing, squatting and lying on the elevator car or platform.

The pier bottom (full load) test is carried out on the elevator test derrick. Simulate the free fall of a fully loaded car and impact the buffer under the allowable operating speed range of the buffer and overspeed. The free fall height is 75mm, 500mm and 1000mm respectively, in which the free fall height of 75mm impacts the buffer, and the converted impact speed is the allowable impact speed of the buffer.

3. Results and discussions

3.1. Impact load and displacement curve

Some experimental curves under three working conditions: no-load up brake braking, full load down brake braking and full load down safety clamp braking are shown in Fig. 2. As can be seen from the figure, the displacement value of the lumbar spine is much greater than that of the upper neck.

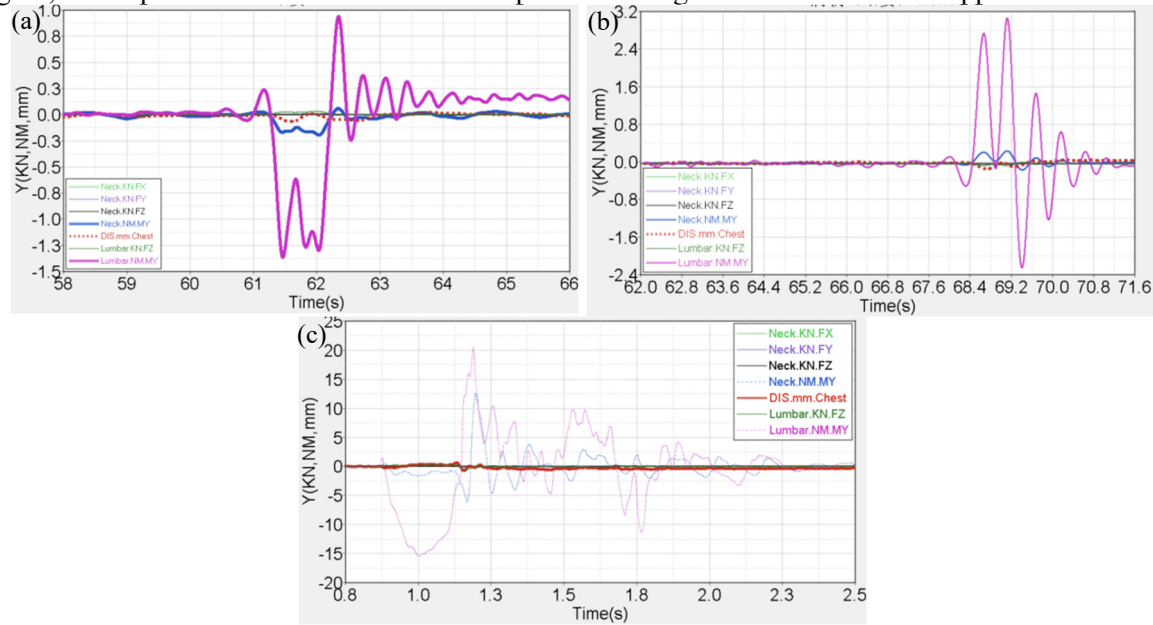


Figure 2. Curves under different working conditions.

The experimental curve of the elevator car under the condition of full load pier bottom from 75mm, 500mm and 1000mm away from the buffer is shown in Fig. 3.

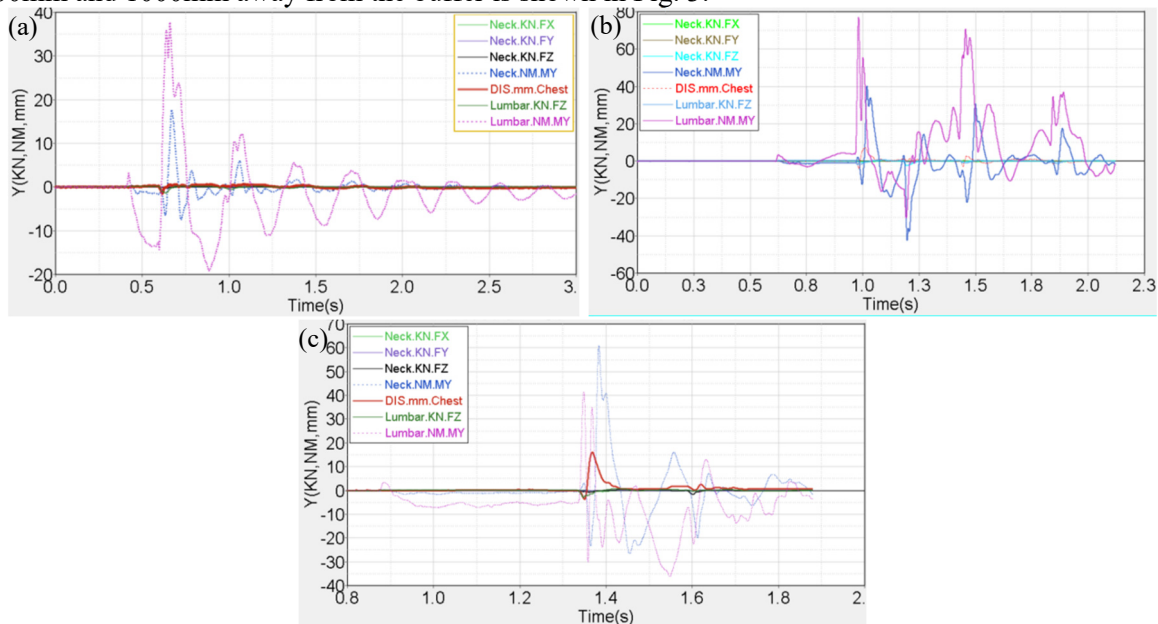


Figure 3. The pier bottom experimental curves.

3.2. Experimental data analysis

The maximum values (absolute values) of upper neck force, lumbar force and chest rib displacement under various working conditions are shown in Table 1, Table 2 and Table 3 respectively. Through the

comparative analysis of the data, it can be concluded that under the two working conditions of no-load up brake braking and full load down brake braking, there is little difference in the impact load and torque of upper neck, the impact load of lumbar vertebra and the displacement of chest ribs. Under the braking condition of fully loaded downward safety clamp braking, the torque of upper neck, chest rib displacement and lumbar vertebra increase significantly. Under the condition of full load pier bottom, the maximum value (absolute value) of force on the upper neck and lumbar vertebra and chest rib displacement are much greater than those under the other three test conditions. Under the condition of full load pier bottom, the stress and displacement of each part increase obviously with the increase of drop height. When the action speed of the buffer is exceeded, the force and displacement of each part of the dummy increase significantly. During the field test, it is obviously observed that when the drop height is 500mm, fracture occurred at the knee of the dummy's left leg, and when the drop height increases to 1000mm, the knee of the dummy's left leg is broken.

Table 1. Maximum load on upper neck (absolute value).

	no-load up brake braking	full load down brake braking	full load down safety clamp braking	full load pier bottom from 75mm	full load pier bottom from 500mm	full load pier bottom from 1000mm
F_x/kN	0.0026	0.0034	-0.108	-0.160	-0.388	0.187
F_y/kN	0.0018	0.0008	0.0318	0.0630	-0.187	-0.16
F_z/kN	0.0067	-0.007	0.0697	-0.227	-2.271	-1.68
$M_y/\text{N}\cdot\text{m}$	-0.194	0.2666	12.598	17.654	-42.54	60.77

Table 2. Maximum load on lumbar vertebra (absolute value).

	no-load up brake braking	full load down brake braking	full load down safety clamp braking	full load pier bottom from 75mm	full load pier bottom from 500mm	full load pier bottom from 1000mm
F_z/kN	0.0325	-0.043	-0.522	-1.365	-1.952	-2.90
$M_y/\text{N}\cdot\text{m}$	-1.366	3.0892	20.438	37.702	77.167	41.64

Table 3. Maximum displacement of chest rib (absolute value).

	no-load up brake braking	full load down brake braking	full load down safety clamp braking	full load pier bottom from 75mm	full load pier bottom from 500mm	full load pier bottom from 1000mm
DIS	-0.066	-0.118	-0.697	-1.467	6.9499	16.02

4. Conclusion

Through the experimental research under different working conditions and different postures, the following conclusions can be obtained:

In standing posture, in the above four working conditions, compared with the other three working conditions, the stress on cervical spine, chest rib displacement and lumbar spine are the largest. Therefore, when the bottle bottom is fully loaded, human injury is the largest. Under the working condition of full load pier bottom, if the speed range allowed by the buffer is exceeded, people will be injured, and the degree of injury will increase significantly with the increase of falling height.

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