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Study on Poor Ergonomics of the Brake Pedal of Passenger Vehicles

Pang Qianyue[1,a,*], Chen Yike[1,b], Xiong Le[1,c]

[1]CRRC Electric Vehicle Co., Ltd., Zhuzhou, China
[a]957641369@qq.com, [b]15767300@qq.com, [c]406789617@qq.com
[*]Corresponding author

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Abstract: For a vehicle, the brake pedal is a crucial component, allowing control over the vehicle's braking system by pressing the brake pedal, thereby achieving deceleration or bringing the vehicle to a stop. If the brake pedal has poor ergonomics, preventing it from being pressed to its extreme position, it can lead to reduced braking efficiency, increased braking distance, uneven braking, driver fatigue, and other issues. This directly affects the vehicle's road safety, increases the risk of accidents, and poses a threat to the safety of both the driver and passengers. The paper systematically analyzes the main parameters contributing to this issue, proposes rectification suggestions, addresses the problem of inadequate pedal ergonomics, and provides ideas and references for solving such problems.

1. Introduction

When a certain type of passenger vehicle is used in the southwestern region of China, feedback has been received regarding poor human-machine interaction in the brake pedal. Specifically, when the driver fully depresses the brake pedal to what should be its extreme position in terms of leg reach, the pedal does not reach this intended position. Consequently, the vehicle cannot come to a stop at the expected location, significantly impacting the driving and passenger experience as well as road safety.

Numerous factors can lead to poor human-machine interaction in the brake pedal. Issues such as inadequate pedal placement and inappropriate system parameter design can affect the operability of the brake pedal. This paper, in the context of a particular passenger vehicle model experiencing issues with human-machine interaction, employs virtual simulation to replicate real driving conditions. It systematically analyzes the parameters affecting pedal placement, provides a detailed exposition of their influence on pedal operation, and, through corrective measures, resolves the problem of poor human-machine interaction in the brake pedal to ensure road safety.

2. Simulation of Driving Conditions

2.1. Digital Human Body Model Development

At the end of 2019, the Institute of Basic Standardization Research at the China National

Institute of Standardization completed the latest anthropometric baseline parameter survey and data analysis for Chinese adults. Given that a majority of car drivers are male, based on the collected recent anthropometric data, P5, P50, and P95 percentile male digital human body models were developed in RAMSIS.

2.2. Driving Condition Simulation

In the analysis, multiple extreme positions are often chosen for simulation analysis. Two static postures of extreme positions during the stepping process are selected for driving condition analysis. In RAMSIS, different percentile human body models will have constraints on key nodes. RAMSIS computes the best driving posture based on the specified constraints. The first posture is the sitting posture where the right foot is placed on the brake pedal but not pressed. The constraints for the first posture are as follows: the human body model's H-point and the foremost, lowest position of the seat design stroke frame; the right foot heel point and the pedal compression plane; the right foot tread point and the pedal plane; the sole of the right foot parallel to the pedal plane; the left foot heel point and the floor compression plane; the left foot tread point and the floor compression plane; both hands grip points and the steering wheel curved surface; dual-hand grip posture.[1]

The second posture is the sitting posture where the right foot presses the brake pedal to the extreme position. The constraints for the second posture are as follows: fixing the H-point position from posture one; the right foot tread point and the pedal plane (the position relative to the pedal plane is consistent with posture one); the sole of the right foot parallel to the pedal plane; the left foot heel point and the floor compression plane; the left foot tread point and the floor compression plane; both hands grip points and the steering wheel curved surface; dual-hand grip posture.

Simulations for different percentiles revealed that after applying the constraints for posture two, the ankle joint angle for the P5 percentile human body was already at the physiological limit of 125°[2] (Figure 1), indicating that for smaller percentile human bodies, reaching the extreme position of pressing the brake pedal is difficult. According to relevant human body data surveys, it is known that human dimensions, such as average height, in the southwestern region, are below the national average. Therefore, for the southwestern market, there is indeed a human-machine interface issue with this vehicle model.

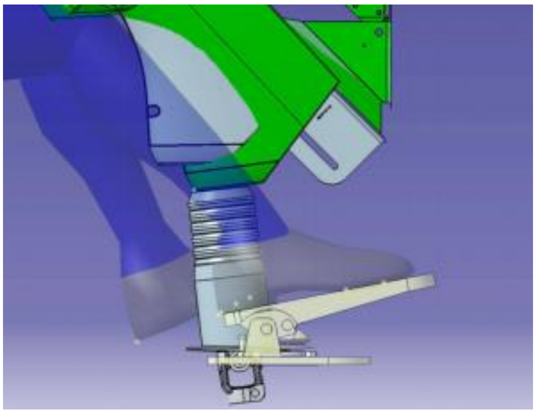

Figure 1: Driving Condition Simulation

3. Cause Analysis

Starting from the issue of human-machine interaction with the brake pedal, we have selected three key parameters related to this problem for a detailed analysis. These parameters are the X-direction distance from the bottom of the brake pedal to the R-point, the idle position of the brake pedal in terms of horizontal angle, and the brake pedal travel angle, as shown in Figure 2.

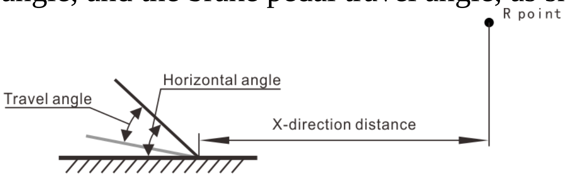

Figure 2: Pedal Layout Parameters

3.1. The X-direction distance from the bottom of the brake pedal to the R-point

The X-direction distance from the bottom of the brake pedal to the R-point in a certain passenger vehicle model is 680mm. This distance, when excessive, results in difficulties for the small percentile population to reach and step on the pedal even when seated in the foremost and lowest position.

In RAMSIS, with the H-point fixed, reducing the X-direction distance from the bottom of the brake pedal to the R-point by 20mm allows the 5th percentile of the human body to step on the pedal to the extreme within the range of joint angles. However, while continuously decreasing this value with a 10mm change increment, it is found that as this value decreases, overall discomfort of the human body increases slightly but gradually, with a noticeable increase in discomfort of the right leg, as shown in Table 1.

Table 1: Influence of X-direction distance from pedal bottom to R-point on Comfort

Distance	Overall Discomfort	Right Leg Discomfort
680mm	3.19	2.19
670mm	3.21	2.50
650mm	3.17	2.68
640mm	3.25	2.95
630mm	3.26	3.23
620mm	3.27	3.56
610mm	3.29	3.95
600mm	3.30	4.40

Reducing the X-direction distance from the bottom of the brake pedal to the R-point does indeed resolve the issue of the lower percentile individuals not being able to reach the brake pedal to the extreme. However, this reduction should not be carried out indiscriminately, and consideration should also be given to the ergonomic comfort of human operation. Additionally, when the throttle pedal layout remains unchanged, decreasing this value creates a front-to-rear gap between the throttle pedal and the accelerator pedal. This affects the transition operation between the two pedals during driving, thereby influencing the overall driving experience.

3.2. The idle position of the brake pedal in terms of its horizontal angle

The idle position of the brake pedal concerning the horizontal angle is 43 degrees for a certain passenger vehicle model. The specified range for this angle is 43° to 60°, with a recommended range of 43° to 49°.[3] A value below the lower limit of this range may lead to difficulties for the lower percentile of individuals in reaching the pedal, even when considering the same pedal travel and seating position.

In the RAMSIS software, by maintaining a fixed H-point of the human body model, increasing the idle position angle of the brake pedal by 3 degrees enables the 5th percentile human body to operate the pedal within the range of joint angles. However, with a continuous increase in this value, using a 2-degree increment, it was observed that as this angle increases, the overall discomfort of the human body in the idle position slightly rises, with a more pronounced increase in discomfort in the right leg. When the pedal is fully depressed, the overall discomfort of the human body also increases slightly but to a lesser extent, while the discomfort in the right leg significantly decreases, as shown in Table 2.

Table 2: Influence of idle pedal position and horizontal angle on Comfort

Angle	Overall Discomfort in an idle state	Right Leg Discomfort in idle state	Overall discomfort in an extreme state	Right Leg Discomfort in an extreme state
43 °	3.19	2.19	3.13	2.80
45 °	3.18	2.44	3.14	2.06
47 °	3.18	2.75	3.15	1.58
49 °	3.18	3.14	3.15	1.32
51 °	3.18	3.61	3.16	1.21
53 °	3.18	4.17	3.17	1.18
55 °	3.21	4.74	3.18	1.19
57 °	3.21	5.47	3.18	1.22
59 °	3.22	6.24	3.19	1.25

Indeed, increasing the idle position angle of the brake pedal concerning the horizontal angle can address the issue of the lower percentile of individuals being unable to reach the pedal's extreme position. However, this increase should not be done indiscriminately; consideration must also be given to human comfort during operation. It is advisable to strike a balance, ensuring that the comfort in both pedal states remains at a satisfactory level.

3.3. Brake pedal travel angle

The brake pedal travel for a certain bus model is 32 degrees, whereas the specified range is 20 to 30 degrees, with a recommended value of 25 degrees. An excessive pedal travel angle can lead to difficulties for the lower percentile of individuals to depress the pedal when seated at the foremost and lowest position of the seat.

In the RAMSIS simulation, with the human body model H-point fixed, reducing the brake pedal travel angle by 2 degrees allows 5th percentile individuals to depress the pedal to the limit within the range of articulation of their joints. However, a continuous decrease of this value in 2-degree increments results in a slight increase in overall discomfort but with minimal variation. Notably, discomfort in the right leg decreases significantly as this value is reduced, as shown in Table 3.

Table 3 Influence of brake pedal travel angle on Comfort

Travel Angle	Overall Discomfort	Right Leg Discomfort
32 °	3.13	2.80
30 °	3.15	1.92
28 °	3.16	1.47
26 °	3.17	1.29
24 °	3.18	1.25
22 °	3.19	1.27
20 °	3.19	1.30

Reducing the brake pedal travel angle does indeed resolve the issue of the lower percentile being unable to depress the pedal to the limit, and with the decrease in angle, the comfort in the right leg at the limit position consistently improves. However, this travel angle is subject to constraints imposed by the brake system's design and other engineering-related limitations, necessitating adjustments in consideration of these engineering constraints.

4. Rectification Measures

Following the above analysis, there are several methods to address the human-machine interface issue with the brake pedal in this particular passenger vehicle. Taking into account the minimal overall impact on the vehicle, it was decided to increase the idle angle of the brake pedal. Considering on-site conditions and engineering constraints, the idle angle of the brake pedal was adjusted from 43 °to 51 °.

5. Conclusion

Tracking of the prototype vehicle after the modification confirmed the resolution of the human-machine interface issue with the brake pedal. This paper primarily described the phenomenon of the pedal human-machine interface issue, elaborated on how to analyze the layout parameters related to the issue, optimized the brake pedal idle angle, and conducted market tracking verification. This led to an effective resolution of the human-machine interface issue, thereby enhancing the product's human-machine performance. It also provides a reference method for the analysis of similar problems."

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