Model Construction and Analysis of Comfortbility for High-Speed Rail Chair Surface

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Abstract The seat comfort of high-speed rail has a greater impact on the overall comfort of high-speed rail. However, the existing high-speed rail seat cushion surface has poor fit with human buttocks and thighs. In sitting for a long time, the front end of the cushion shape will affect leg muscle comfort and other issues seriously affect passengers' travel experience. In this paper, the comfort between seat cushion and human body contact surface of high-speed train is studied by combining subjective and objective methods. The main research contents are as follows: (1) In order to explore the influence of sitting posture on comfort of high-speed railway chair surface, the study of rectified sitting posture and relaxed sitting posture is carried out. (2) Analyzing the factors affecting the comfort of passenger seats in the human-seat-environment system, and on this basis, starting from the Ergonomics of seats, processing the important parameters data related to the static comfort of seats, trying to get the best sitting posture of the subjects. (3) According to the existing seat parameters (the best cushion indentation hardness, cushion thickness, cushion material hardness, etc.) and the characteristics of cushion surface morphological variables, we try to design various surface morphological models of high-speed rail seat cushion. (4) To divide the contact area between chairs and people on the cushion, get the unit pressure data at the pressure points of different cushion areas based on ACTILUS pressure sensor system, and use the method of body pressure distribution to calculate and analyze the Seat Pressure Distribution index (SPD%) of the body pressure distribution characteristics on different cushions, so as to find the best surface shape of the cushion. (5) The subjective method mainly adopts the Seven-level comfort evaluation scale, focusing on the comfort score of key parts of the human body. The research is of great significance to improve the comfort quality of high-speed trains and enrich the ergonomics theory of high-speed trains in China.

Keywords: high speed rail seat, body pressure distribution, seat cushion body contact surface, cushion surface shape.

1 Introduction

Nowadays, the backrest of domestic high-speed rail seats is adjustable within a limited range, and the angle of the seat cushion is generally fixed. During the operation of high-speed rail, the design of the seat is directly related to the passenger's riding experience. For example, a good seat design can ease the passenger's nervousness from noisy environment, and a well-designed seat can make the passenger get the maximum rest. Resting and stretching, designing seat cushions that are in line with human physiological characteristics can effectively reduce passengers' risk of sitting sores and other skeletal diseases.

Comfort is one of the sensory mechanisms of human beings. Comfort is a person's response to the whole environmental system when he touches objects. Hterzberg points out that comfort and discomfort are two opposite situations. They are different sensory systems. The correct explanation of human comfort is that there is no uncomfortable feeling. The influence factors of comfort degree of high-speed train mainly include physical factors, human physiological factors and human psychological factors. Nowadays, there are three main research methods on seat comfort of high-speed train: subjective comfort, objective comfort and the combination of the two. In the research of subjective comfort, the comfort performance of each part of high-speed rail seats is validated by establishing comfort model and comfort measurement scale, such as GCR [1], BPD (40), Dannion R. Smith questionnaire and CEC (21). Mainly through surface electromyography, body pressure distribution, vertebral load and other physical means, according to seat-related parameters data analysis, test seat comfort situation; some scholars research is the combination of the two, explore various subjective and objective factors related to seat comfort, such as Yang Zhongliang [3] found only objective. The results of the study are rigorous in evaluating the comfort of high-speed rail seats. Subjective testing and evaluation are indispensable to the comfort test of sitting posture. The research on comfort degree of high-speed rail seats includes static comfort degree and dynamic comfort degree. Static comfort is mostly related to the seat's own characteristics, such as size ratio, material selection, reasonable structure and so on. Zhao Ling [2] and other methods of body pressure distribution were used to compare the running state and static state of the car body. It was found that there was no significant difference in the body pressure distribution between the two methods. Therefore, it is of great reference significance to carry out the experiment of body pressure distribution in the experimental environment for the study of static comfort. Dynamic comfort is mostly related to the body structure and running environment of the high-speed railway in its own running state, such as the vibration frequency or the air pressure of the carriage when the high-speed railway is running. Drummond et al. pointed out that in sitting posture, the ischial tubercle shoulders part of the body weight, up to 18%. In the buttock region, the reasonable pressure distribution should be the maximum pressure at the ischial tubercle, and then gradually decreases to all sides.

Denis Zacharkow [4] found in his research that hip is one of the important factors that influence each other in the key parts of human body which are related to seat comfort. Human body pressure distribution can not only test the body pressure distribution of the corresponding parts, but also find the theoretical relationship between hip and seat comfort through rigorous data analysis, which provides a basis for the study of seat comfort. Based on the theoretical and scientific basis, more relevant comfort evaluation indicators are explored.In the research of seat comfort, pressure distribution can establish multi-parameter evaluation model based on body pressure distribution criterion, optimize seat shape, soft and hard degree and other parameters, and then effectively guide seat structure design, reasonable layout of man-machine and improve ride comfort. The study of pressure distribution plays an obvious guiding role in the study of ride comfort of trains in short-term or long-term operation.

2 Method

2.1 Participant

The object of this study is passengers on high-speed trains. The number of passengers is huge. Given the limitations of time and conditions, it is impossible to carry out experiments on all the subjects. Therefore, before doing the sample survey experiment, we should first determine the reliable sample size that can effectively infer the overall. Because the research object of this paper is very extensive, the acquisition of reliable sample size needs three essential conditions: first, reliable sample size needs to cover a wide range of human body size required by the experimental object; second, these broad human body size should conform to normal distribution; third, the size of sample size should be effective, reflecting the general situation.

In this study, a simple random sample size calculation method [5] was used to obtain the minimum sample size of 96. The sample size conforms to the normal distribution, and the height and weight are between the 5th percentile and the 95th percentile. In this research, 96 samples will be used for subjective evaluation of comfort of high-speed rail chair. In the measurement of body pressure distribution, due to the limitation of experimental time and conditions, two subjects of large, medium and small stature will be selected from 96 samples, each male and female.

2.2 Materials

In view of the comprehensive consideration of the size, accuracy and ductility of the pressure sensor, the cushion pressure sensor test system of TACTILUS model is adopted in this experiment. It can display the pressure value of each sensor unit in real time, as well as the two-dimensional and three-dimensional graphics display. It can display the minimum and maximum graphics in basic colors such as blue, green, yellow and red. At the same time, it can record and store the whole measurement process. The recorded files can be imported into the corresponding software to reproduce the state of the whole recording process. For the output data documents, the system can also support the conversion of mechanical units such as PSI, RAW, mmh, Kpa and so on, accurate to the decimal point 4-digit value.

TACTILUS cushion pressure sensing system is simple and convenient to use. It can record and obtain experimental data and graphics in real time only by placing the sensor cushion on the test seat, connecting an external processor at the corner of the cushion, connecting the computer at one end of the processor and opening TACTILUS software on the computer.

2.3 Procedure

2.3.1 Subjective evaluation measurement

In order to more accurately understand the influence of comfort degree of key parts on comfort degree of high-speed railway chair, the key parts were selected as buttocks, ischial tubercles, thighs, thighs, roots, knees, legs, feet and ankles; the comfort evaluation scale was Seven-level scale, and the comfort level was 1 to 7 points. The experimental scoring steps are as follows:

(1) Before the experiment, the participants were explained the location and range of the body parts in the scale, and the degree and significance of each score of the Seven-level score.

(2) After adjusting the experimental seat, the subjects sat on the cushions of S1, S2 and S3 for 5 minutes in an rectified sitting position, and compared with the lower limb position map, as shown in Figure 4-3, the comfort degree of the human body was scored on each cushion.

(3) After adjusting the experimental seat, the subjects were seated on the cushions of S1, S2 and S3 in a natural relaxation position for 5 minutes, and compared with the lower limb position map, as shown in Figure 4-3, the comfort degree of the human body was scored on each cushion.

(4) Which level should the subjects choose to draw "√" in the corresponding blanks.

2.3.2 Objective body pressure distribution measurement

To measure the pressure distribution of the high-speed rail chair in simulated experimental environment, the force calibration range is carried out on TACTILUS software before the measurement. The pressure unit is PSI. As shown in Figure 4-4, the test temperature is required to be 23 (+%) 2 and the relative humidity is 60 (+) 4%. The test subjects are required to wear shirts: 100% pure cotton, underclothes: 50% polyester and 50% pure cotton, jackets: 55% polyester and 55% pure cotton. 45% wool; the seat before the test is placed in the experimental environment for 24 hours; the subjects rest for 1 hour in the experimental environment before the test, and then test when they feel most comfortable. For the convenience of recording data, the seat cushion in the following article is called as follows:

The protruding cushions on both sides in the rectified sitting posture are C-S1.

The front protruding cushion in the rectified sitting position is C-S2.

The flat protruding cushion under the rectified sitting position is C-S1.

The protruding cushions on both sides under relaxed sitting posture are R-S1.

The front protruding cushion under relaxed sitting posture is R-S2.

The flat cushion in relaxed sitting position is R-S3.

3 Results

Through the subjects'comfort scores of different parts of the human body made by two sitting postures for three different curved cushions (because they are two sitting postures, the C-S1 in the following article represents the situation of the cushion S1 in the rectified sitting posture, and so on C-S2, C-S3, R-S1 represents the situation of the cushion S1 in the natural relaxation sitting posture, and so on, R-S2, R-S3) we get:

(1) In the rectified sitting posture, the average score of comfort of all parts of the human body is listed, and the standard deviation SD is in parentheses.

Table.1. A List of Means of Comfort Scores for Human Parts in Sitting Posture.

Cushion	Hips	Ischial Tubercle	thigh	Root of thigh	Knee joint	A lower leg	Ankle	Feet	Overall comfort
S1	4.64（0.90）	4.50（0.89）	4.54（0.96）	4.52（1.05）	4.50（0.96）	4.28（0.95）	4.30（0.97）	4.25（1.02）	4.41（0.89）
S2	5.00（1.03）	5.02（0.98）	4.25（0,96）	4.36（0.92）	4.68（0.98）	4.63（0.95）	4.59（0.94）	4.68（1.02）	4.65（0.95）
S3	5.04（1.03）	4.98（0.97）	4.75（1.01）	4.65（0,92）	4.50（0.95）	4.43（0.99）	4.52（0.96）	4.36（0.94）	4.67（0.85）

(2) Under the natural relaxation sitting posture, the average score of comfort of all parts of the human body is listed, and the standard SD is in parentheses.

Table.2. A list of average comfort scores for different parts of the human body in natural relaxation sitting posture.

Cushion	Hips	Ischial tubercle	thigh	Root of thigh	Knee joint	A lower leg	Ankle	Feet	Overall comfort
S1	4.47（0.95）	4.40（0.86）	4.64（0.93）	4.58（1.01）	4.47（0.97）	4.35（0.98）	4.26（0.87）	4.23（1.03）	4.42（0.94）
S2	4.46（0.95）	4.35（0.89）	4.32（0.94）	4.26（0.98）	4.43（0.97）	4.53（1.03）	4.35（0.97）	4.30（0.99）	4.37（0.92）
S3	4.53（0.92）	4.40（0.98）	4.57（0.89）	4.62（0.96）	4.35（0.85）	4.55（0.98）	4.43（0.91）	4.31（0.97）	4.47（0.87）

The data were collated and analyzed. The results showed that the two-dimensional pressure distribution icon of the subjects was shown in Table 5-3, and the body pressure data of the cushions in two sitting positions were shown in Table 5-4.

Pre-experiment: In order to explore which sitting posture has better comfort experience for high-speed railway passengers under the two situations of rectified sitting posture and natural relaxation sitting posture, the two-dimensional pressure distribution maps of three cushions S1, S2, S 3, maximum pressure Pm, average pressure Pv and contact surface of a participant (a 23-year-old woman with a height of 160cm and a weight of 45kg) were analyzed first in the two situations of rectified sitting posture and natural relaxation sitting posture. Product A, mass center C data, to compare the impact of two sitting postures on the same subject.

The sampling time of TACTILUS is 5 minutes and the sampling frequency is 5 frames per second. The subjects have 1500 frames of pressure distribution experimental data on each cushion. The data is derived in the form of TXT file. Before the test data is applied to the experimental analysis, it should be pretreated first to reduce the human control error in data collection. In addition, TACTILUS sensor system can intuitively output the maximum pressure Pm, average pressure Pv, contact area A, mass center C and two-dimensional pressure distribution of the cushion.

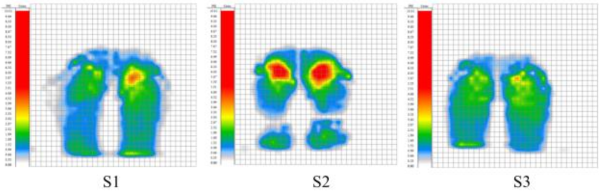

Fig.1. Two-Dimensional Pressure Distribution in Rectified Sitting Posture

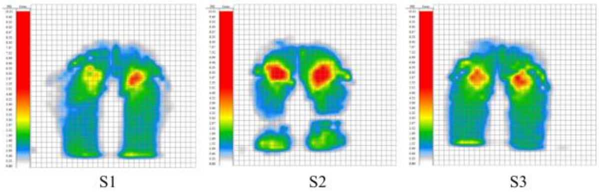

Fig.2. Two-Dimensional Pressure Distribution in Relaxation Sitting Posture

4 Discussion

The highest overall comfort score was S3 flat cushion, followed by S2 and S1. For S1 lateral convex cushion, the comfort of lower limbs is relatively average, and the comfort of lower limbs is more balanced; the comfort of S2 front protruding cushion buttock area is higher than that of leg part, which indicates that the front protruding cushion is beneficial to relieve the pressure of buttock area; the comfort of S3 flat cushion buttock and thigh area is better than that of S2 front protruding cushion buttock area. The effect is the best. The comfort degree of calf and knee joint is worse than that of the former two. Flat cushion can not effectively disperse the pressure of various parts of human body and improve the comprehensiveness of comfort degree compared with S1 cushion. The highest overall comfort score was S3 flat cushion, followed by S1 and S2. In relaxed sitting position, the comfort of thigh area is better than that of buttocks, calves and feet for S1 lateral convex cushions; the overall comfort of S2 front protruding cushions is more balanced than the other two, of which the comfort score of calf area is the highest; the comfort score of S3 flat cushion thigh area is the highest, and the pressure of flat cushion is lower than the other two for thighs, but the comfort score of S2 front protruding cushions is the highest. It's about knee comfort, which is worse than the other two.

In the case of rectified sitting posture, the contact area between the subjects and the cushion is smaller than that of the relaxed sitting posture, and the same is true for the cushion of each shape. It is found that the center of gravity of the relaxed sitting posture will move downward, resulting in the increase of the contact area with the cushion. With the change of the sitting posture and the cushion surface, the center of gravity of the cushion of the shape of the cushion under each sitting posture also occurs. The displacement indicates that both the sitting position and the cushion surface will affect the weight of the subjects on the cushion. According to the Pm and Pv break-line maps of the cushions in Fig. 5-4, it can be found that the average pressure Pv of the cushions in these six different states has no obvious change, and the average pressure of the cushions in the break-line maps is close to the straight line. The average pressure of the C-S1 cushions is the smallest, and the single factor analysis state is more comfortable than other cushions. The maximum pressure of the R-S2 cushions is the largest, because of the law of cushion pressure, the cushion pressure of the sitting bone The pressure at the nodule is the greatest, and as the center, the pressure expands smoothly from big to small, so the pressure at the nodule of the sciatic bone of the cushion with protruding front is the greatest when relaxing sitting posture. In the case of rectified sitting posture, the pressure on the two sides of the cushion ischial tubercle is the smallest, which is more comfortable for the ischial tubercle. The contact area of the cushion is smaller than that of the whole body in the relaxed sitting posture, and the contact area of the person-cushion in the relaxed sitting posture is larger than that in the rectified sitting posture in three different surface shapes. In theory, the overall comfort of rectified sitting posture is better than that of relaxed sitting posture, and the six states of cushion are more comfortable. The two sides of protruding cushion under rectified sitting posture are more comfortable.

5 Conclusion

Throughout the subjective and objective research on comfort degree of high-speed rail chair surface, static comfort degree research situation, straightening sitting position is more comfortable than relaxing sitting position experience, but passengers in high-speed rail operation behavior, relaxing sitting position occurs most frequently; three different curved surface shape cushions, flat cushion and the rest of the subjective evaluation. Compared with the other two, the front protruding cushion is more comfortable. In objective index evaluation, the front protruding cushion has a certain effect on improving the uniformity of cushion pressure distribution. The flat cushion has the smallest SPD% and the most uniform pressure distribution, which is more comfortable than the other two. Under long-term conditions, the simple index based on comfort score and body pressure data is not the same. It can fully characterize the comfort of high-speed rail chair surface, and in the future, EMG sensing and scene simulation can be added to the experimental study.

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