Research on the Comfortable and Maximum Pedaling Forces of Chinese Population

Huiyu Luo[1], Chang Liu[2], Jing Zhang[1], Qing Ye[1], and Li Ding[1(✉)]

[1] School of Biological Science and Medical Engineering, Beihang University, Beijing, China
dingl971316@buaa.edu.cn
[2] Pan-Asia Technical Automotive Center Co., Ltd., Shanghai, China

Abstract. With the fast development of the automotive designs, auto manufacturers have paid more and more attention to the comfort driving in recent years. Driving pedaling forces, referring to the forces exerted by the drivers on the brake, clutch, and accelerator pedals when they are driving cars, are ergonomic evaluation indices of human-vehicle interaction. Nowadays, there are few researches on the pedal comfort of the Chinese population. Therefore, this paper aims to study the Chinese drivers' pedaling force data and the factors influencing on it. The experiment facilities were designed to measure the pedaling forces. The research showed that: (1) The dissatisfaction of drivers with the brake pedal is much more than that with clutch, and accelerator pedal, from the view of pedaling forces. (2) The pedaling forces of the subjects show the basic normal distribution. (3) The gender difference has little impact on the comfortable pedaling forces, but there is remarkable difference on the maximum pedaling force acceptable between male and female. (4) The angle of elbow flexion joint has no significant influence on the comfortable pedaling forces, but with the increase of the elbow joint, the maximum pedaling forces acceptable declines.

Keywords: Ergonomics · Comfort driving · Pedaling force

1 Introduction

Automobile comfort research is a part of the fine design of automobile, and the research is significant for both automobile manufacturers and drivers. On the one hand, the automobile manufacturers can improve their market competitiveness by virtue of comfort research. On the other hand, comfortable driving research not only can make the drivers enjoy the driving pleasure of, but also has important significance for alleviating the car drivers' occupational disease.

Automobile comfort driving research mainly includes two aspects, (a) Adjust the drivers' posture to achieve comfortable driving based on the analysis of the human body and the subjective feelings of the comfortable driving position. In 1975, Rebiffe analysed the drivers' operation process, and calculated the driver comfortable driving angle by establishing the biomechanical model and theoretical analysis [1]. In 1980, Grandjean and Rebiffe did biomechanical analysis by limiting the position of the drivers' head,

V.G. Duffy (Ed.): DHM 2016, LNCS 9745, pp. 32–41, 2016.
DOI: 10.1007/978-3-319-40247-5_4

feet and hands, and worked out the joint angles of the drivers under comfortable driving posture [2]. In 1998, Porter and Gyi obtained the comfortable joint angle by testing 55 subjects, and compared with the data of Porter and Gyi [3]. In 2008, Ma et al. tested the driving comfortable angles (including the back angle, trunk thigh angle, knee angle) with PASSAT and POLO two models [4]. The studies above were carried out under the background that people adapt to the existing vehicles, and the results mainly depended on the subjects' subjective feeling. (b) The seat, steering wheel and pedals are most frequently-used when the drivers driving. Therefore, these three devices play an important role on the comfort driving, and there are many researches concerning the optimization of these three devices, especially the seat. Zhifei Zhang et al. researched on vehicle seat comfort based on the static and dynamic test of body pressure distribution, and compared the differences between dynamic and static pressure indicators. The features of the body pressure are got more clearly based on the research [5]. Matsuoka, who thought that passengers' seats and the drivers' seat should be paid equal attention to meet the comfortable driving and riding requirements, so they did the body pressure distribution researches, and determined the several factors of the comfort of seat design: minimum cushion angle, hip joint to allow the scope of activities, knee joint angle and ankle joint angle [6]. Liu Haoxue et al. provided a reference for the optimization design between brake and accelerator pedal by analyzing the relationship between the height difference of brake and accelerator pedal and the drivers' reaction time [7].

But there are rarely researches about automotive pedals comfort of Chinese population. According to our comfort driving survey in China, nearly half of the participants deemed that the pedaling force needed are too large or too small, which can't meet the requirement of the drivers. Accordingly, this paper aims to find out the comfortable pedaling force of Chinese and the reasons for recent dissatisfaction with the pedal design.

2 Methods

2.1 Research Equipments

The Violet ZG-601MDB driving simulator the Santana seat was used for simulating the driving environment. The pedaling forces are measured and recorded by the pressure measurement system, which consists of two sub-modules, the DAQ module and the software platform. The DAQ module included BD-4K pressure sensor, and in relation to software platform, the Kingview6.55 was adopted.

2.2 Subjects

According to the standard of human body size in China, 510 healthy Chinese drivers were selected to participate in this test, including 260 males and 250 females. Male subjects with an average height of 169.3 cm, maximum height for 195.0 cm, minimum height for 151.0 cm. Their average weight for 66.1 kg, and average driving experience is 6.1 years, longest driving experience for 37 years and shortest driving for 1 month;

right handedness for 239 people, left handedness is 9 and ambidextrous for 2 people. For the female subjects, the average height for 158.2 cm, maximum height for 174.6 cm, minimum height for 144.0 cm; average weight is 55.6 kg, average driving to 4.7 years, longest driving experience 24 years and shortest driving experience for half a month; right handedness for 249 people, left handedness for 10 people and ambidextrous for 1. And the height and weight reference for the subjects selection is shown in Table 1.

Table 1. The height and weight of the subjects

M	Height (m)	<1.540	1.540–1.591	1.591–1.610	1.610–1.693	1.693–1.773	1.773–1.797	1.797–1.854	>1.854
	Number	3	10	13	104	104	13	10	3
	Weight (kg)	<46	46–50.9	50.9–53.5	53.5–64.5	64.5–80.4	80.4–85.9	85.9–95.9	>95.9
	Number	3	10	13	104	104	13	10	3
F	Height (m)	<1.451	1.451–1.482	1.482–1.501	1.501–1.574	1.574–1.650	1.650–1.673	1.673–1.719	>1.719
	Number	2	9	12	102	102	12	9	2
	Weight (kg)	<40.4	40.4–43.6	43.6– 45.5	45.5–55.7	55.7– 69.5	69.5–73.8	73.8–82.0	>82
	Number	2	9	12	102	102	12	9	2

Fig. 1. Experimental scene

2.3 Testing Process

(a) The subjects were asked to adjust the seat to a comfortable position, and the testers recorded the driver's elbow joint, hip angle. (b) Guided the subjects to adapt to the driving environment, and reminded them to keep straight driving. (c) Started driving simulator with slow modules, medium vehicle. And the subjects would operate the clutch, accelerator pedal and the brake plate respectively. (d) When the subjects exerted the defined force, including maximum and comfortable force, they should keep the posture 10 s so that the testers could record data better (Fig. 1). (e) Measured the maximum acceptable stepping force with the same method, and lead subjects to adjust the angle of the elbow joint, including 90 DEG, 120 DEG and 150 DEG and 180 DEG.

3 Analysis and Results

This test was based on Chinese drivers' driving habits and experience, and the data could be applied to the Chinese drivers. Normally the drivers would be cautious in the acceleration process, so the stepping force exerted on the accelerator pedal was minimal, but for the clutch, the drivers need to step on the clutch to the low to complete the shift operation, so the stepping force exerted on the accelerator pedal was maximal. This paper mainly analyzed the subjective evaluation of the three pedals, the distribution characteristics of driving pedaling forces. In addition, the impacts of the different gender and angle of elbow joint on the pedaling force are analyzed respectively.

3.1 Dissatisfaction with the Three Pedals

In this test, the drivers were asked to point out the most uncomfortable pedal among clutch, accelerator pedal and brake pedal, and the evaluation results are shown in Fig. 2. The drivers thought that the most comfortable pedal was accelerator pedal. Only 4 % of the drivers thought that the accelerator pedal was uncomfortable, and the brake pedal and the clutch account for 64 % and 32 % respectively. By the analysis of the figure, the gender differences had no obvious effect on the satisfaction of the pedal.

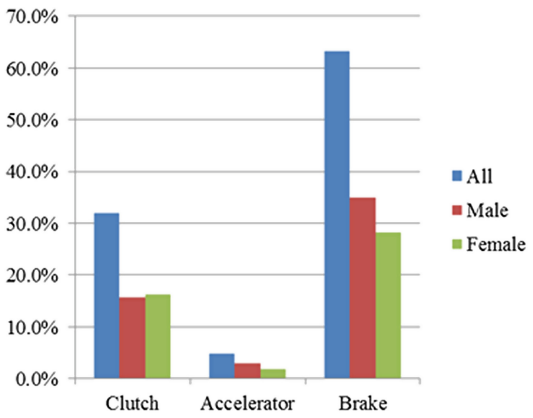

Fig. 2. The percentage of the pedals' dissatisfaction (Color figure online)

3.2 The Force Analysis Based on Gender Differences

Under comfortable sitting posture, the comfortable pedaling force for male is pretty much the same as that for female, but there is a significant different between the maximum pedaling forces acceptable of male and female. As shown in the Fig. 3, for male, the maximum pedaling forces acceptable exerted on the clutch, accelerator and the brake pedal are 148 N, 125 N, and 100 N higher than that of the female separately.

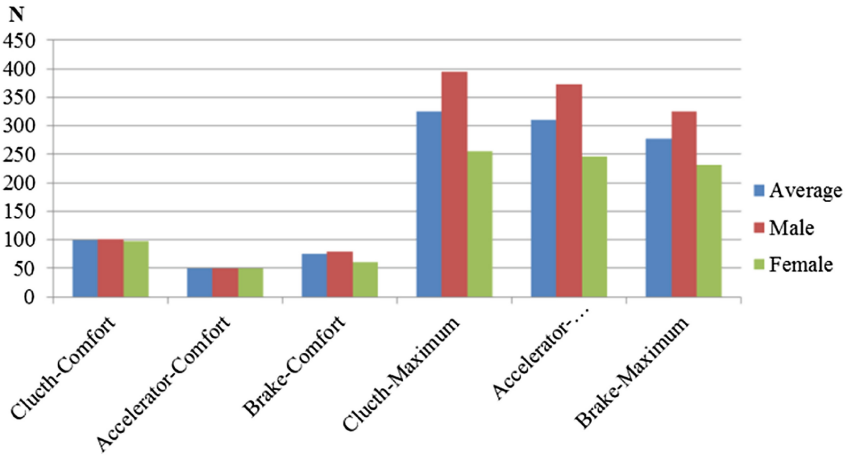

Fig. 3. The pedaling force analysis based on gender differences (Color figure online)

3.3 Data Distribution

In order to verify the data distribution characteristics of the pedaling force, SPSS statistical software is selected to analyze numerical data.

First of all, the normal distribution test was used for the data of the comfortable pedaling force of the clutch, and the figure P-P was shown in Fig. 4, which could prove the data basically fit the normal distribution. And the other pedals and conditions were basically coincident with Fig. 4.

Secondly, the normal distribution maps of the pedaling forces data from different pedals and conditions were shown in Figs. 5, 6, 7, 8, 9 and 10, the characteristic of the forces data distribution were shown clear. For the comfortable pedaling force, the data distribution of the clutch was relatively dispersed, and its average value was 100 N, the standard deviation was 38.6 N. For the accelerator pedal, the data distribution was intensive, and its average value was 52 N, the standard deviation was 19.0 N. The average value of the brake pedal was 78 N, and its standard deviation was 27.6 N. About the maximum acceptable pedaling force, the data distribution was more dispersed, and the numerical values were significantly greater than the comfortable pedaling force.

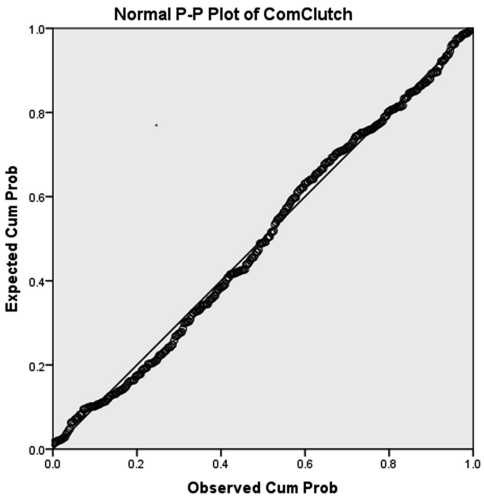

Fig. 4. Normal P-P plot of the comfortable clutch pedaling force

3.4 Pedaling Force Under Different Elbow Flexion Angles

In general, the drivers would exert the comfortable pedaling force on the pedals when they operated the devices, especially, when the drivers operated the accelerator pedal, they would be cautious to avoid accident, so that the stepping force exerted on the

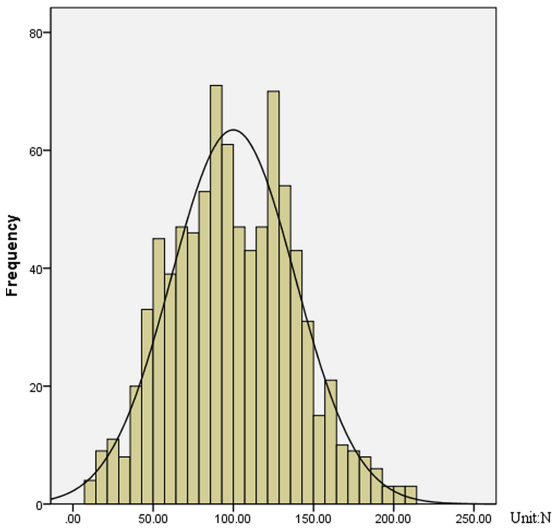

Fig. 5. The normal distribution map of the comfortable clutch pedaling force

accelerator pedal was minimal (see Table 2), for 51 N to 54 N. As the drivers need to step on the clutch to the low to complete the shift operation, and the value of which is about 96 N to 104 N, and the brake pedal for 76 N to 80 N. In addition, by analyzing the relationship between pedaling force under different angle of elbow joint, we found

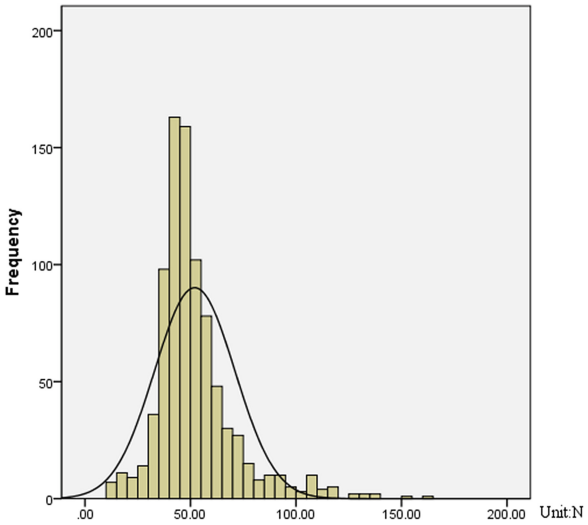

Fig. 6. The normal distribution map of the comfortable accelerator pedaling force

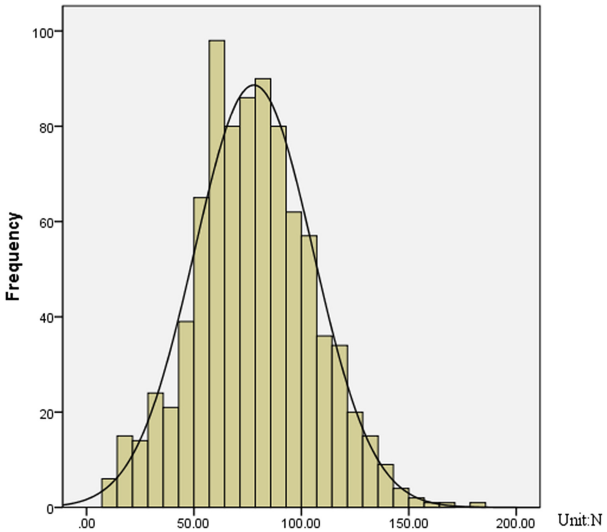

Fig. 7. The normal distribution map of the comfortable brake pedaling force

that the angle of elbow joint has no significant influence on the comfortable pedaling force. But with the angle of elbow joint changing from 90° to 180°, the maximum pedaling force acceptable declined.

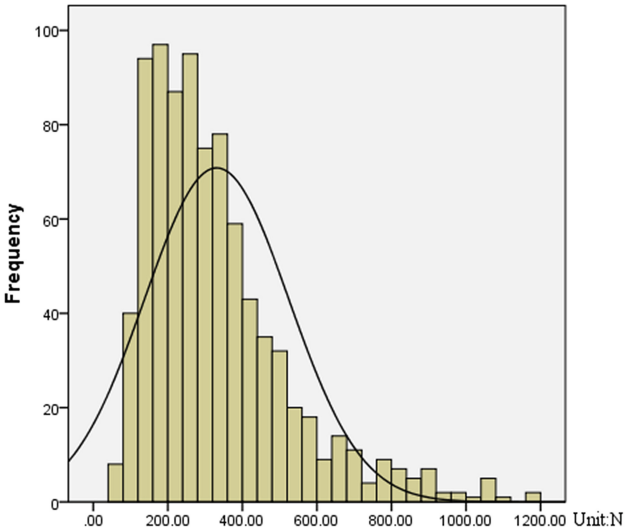

Fig. 8. The normal distribution map of the maximum clutch pedaling force

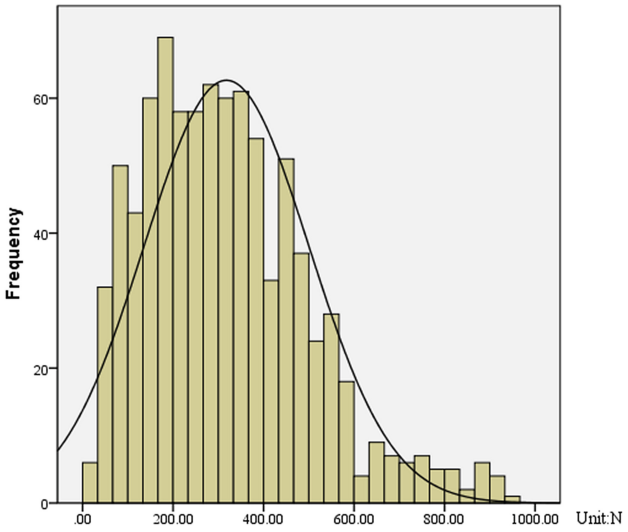

Fig. 9. The normal distribution map of the maximum accelerator pedaling force

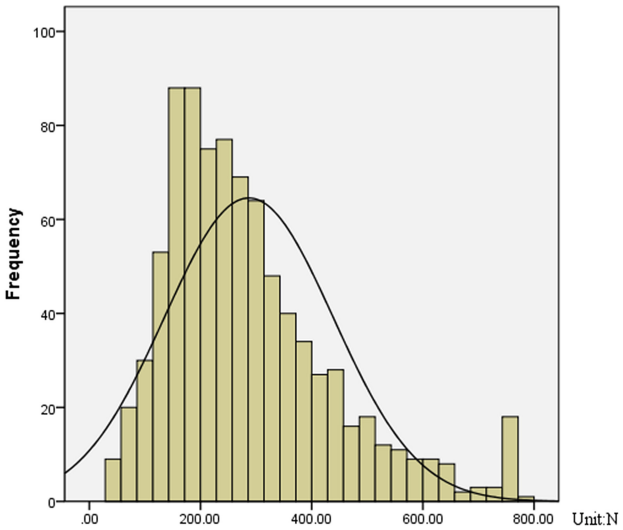

Fig. 10. The normal distribution map of the maximum brake pedaling force

Table 2. The pedaling force among different angles of the elbow joint

Degree	Comfortable pedaling force			Maximum pedaling force		
	Clutch	Accelerator	Brake	Clutch	Accelerator	Brake
Comfort DEG	99.9 ± 3.1	52.0 ± 1.3	77.9 ± 2.2	330.9 ± 13.2	317.9 ± 13.4	286.8 ± 11.1
180 DEG	96.3 ± 3.0	52.1 ± 1.5	76.1 ± 2.0	301.7 ± 14.0	298.4 ± 12.8	289.8 ± 11.7
150 DEG	99.8 ± 2.8	51.9 ± 1.3	80.4 ± 2.1	340.9 ± 14.8	324.4 ± 13.3	278.3 ± 10.2
120 DEG	103.3 ± 2.9	52.9 ± 1.6	77.8 ± 2.2	346.5 ± 15.3	329.3 ± 14.7	296.9 ± 12.4
90 DEG	97.21 ± 2.8	53.3 ± 1.5	79.8 ± 2.0	351.5 ± 15.9	338.9 ± 15.0	299.6 ± 12.2

Unit: N

4 Conclusion

(a) According to the subjective assessment of the drivers, they showed the least satisfaction with the brake pedal. (b) The comfortable pedaling forces on the three pedals are various; the maximum pedaling forces acceptable would be affected by the gender factor. (c) The angle of elbow joint had less connection with the comfortable pedaling force, yet the angle of elbow joint would affect the maximum acceptable pedaling forces.

Acknowledgements. The study was supported by the National Key Technology R&D Program (2014BAK01B05) and National Natural Science Foundation of China (51175021).

References

1. Rebiffe, M.P.: The driving seat: its adaptation to functional and anthropometric requirements. In: Proceedings of a Symposium on Sitting Posture, 132–147 (1969)
2. Grandjean, E.: Sitting posture of car drivers form the point of view of ergonomics. Hum. Factors Transp. Res. **2**, 205–213 (1980)
3. Porter, J.M., Gyi, D.E.: Exploring the optimum posture for driver comfort. Int. J. Veh. Des. **19** (1), 255–266 (1998)
4. Ma, M., Fan, R., Ruan, Y.: The test of comfortable driving posture and the fuzzy evaluation of the comfort. Eng. Manag. **2008**(13), 121–125 (2008). doi:10.3969/j.issn.1007-5429.2008.04.025
5. Zhang, Z.F.: A Study on the Ride Comfort of Vehicle Seats Based on Body Pressure Distribution
6. Matsuoka, Y., Hanai, T.: Study of comfortable sitting posture. SAE paper no. 880054 (1988)
7. Liu, H.X.: A Study of the Effects on Working Efficiency of the Height Difference Between Acceleration Pedal and Brake Pedal