

Prediction of Fit Feeling of Motorcycle Seats Using Body Pressure Distribution Simulation

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ABSTRACT

A measurement standard model of the buttocks shape was made. This model represented the average body pressure distribution of Japanese. The distribution data of Japanese, American, and European were measured and compared by using Buttocks Characteristic Index. The pressure body distributions for each category of motorcycle seats were measured using the measurement standard model of hip shape. Correlation between the measured distribution data and the fit feeling evaluation was analyzed. Based on the analysis, a prediction equation of fit feeling was devised. A simulation model of body pressure distribution was created using Finite Element Method. The simulation model was substituted for the measured distribution data in the prediction equation. A prediction method of fit feeling has been established. The established method has allowed early prediction of the fit feeling for motorcycle seats during the design stage.

1. Introduction

Motorcycle seat performance specifications can be broadly categorized as static seating comfort, dynamic ride comfort, and long-term fatigue level. In evaluating these performances, great differences may be evident, depending on the physique of the person carrying out the testing, especially their buttocks characteristics. Therefore, the authors have established a buttocks characteristic index, an index that expresses the differences in human buttocks characteristics, and have categorized people making the tests according to this index. In addition, a formula to predict static fit feeling was created, using the buttocks characteristic index and data concerning body pressure distribution when the test subject is seated⁽¹⁾. However, human buttocks change over time, and so it is necessary to confirm the characteristics

of buttocks periodically.

To create a method for predicting the fit feeling at the design stage, it is necessary find the correlation between seat design parameters (hardness, shape, material, etc.) and the fit feeling evaluation. In order to carry out this analysis, the focus was placed on body pressure distribution, which is a characteristic value between design parameters and fit feeling. Human body pressure distribution shows the results of design parameter changes, and is thought to be closely linked to fit feeling.

In order to create a standard model, data concerning the buttocks of people in various countries was collected. Simulations were carried out, and finite element models were created of the standard buttocks model and of the motorcycle seat. By determining body pressure distribution, trial predictions were made of fit feeling, at the design stage.

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2. Measurements of Buttocks Area Body Pressure Distribution

In order to create the standard buttocks model, body pressure distribution was measured when the subjects were seated on a reference seat (500 mm × 500 mm × 50 mm urethane). An example of these body pressure distribution measurements is given in Fig. 1. Measurements were made of men and women between the ages of 25 and 50 from various countries; Table 1 shows the number of sample and average age of subjects by country.

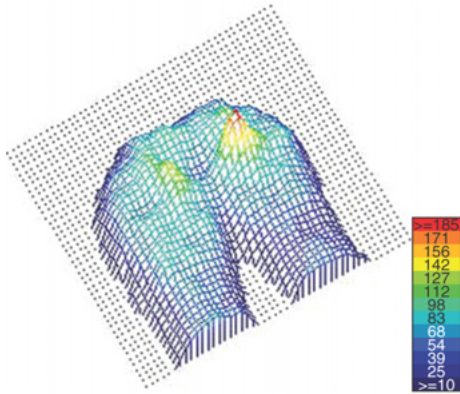


Fig. 1 Sample of measured body pressure distribution

Table 1 Sample number by country

	Number of sample		Average age	
	Males	Females	Males	Females
Japan	100	100	38.8	31.5
France	80	60	41.4	38.1
Italy	110	100	33.2	28
Germany	80	60	38.3	39.1
U.S.A	150	115	41.4	38.1

3. Establishing the Standard Model

3.1. Model Categorization

From the buttocks area body pressure distribution data, contact area was established as the parameter expressing the size of the buttocks area; contact surface pressure variation and kurtosis were established as the parameters expressing load on the buttocks, shape of the buttocks, and fleshiness. In order to bring out the buttocks characteristics for the men and women of each country, principal component analysis was implemented. The results are given in Tables 2, 3 and 4. As a result, the focus was placed on contact area, which has a high cumulative contribution and which is thought to express the size of the buttocks. Verification was made of average value difference of buttocks contact area. These results are shown in Table 5. There were four categories of models having a significant difference of 5% or more: the Japanese model, German Model, Italian and French model, and American model. Figure 2 shows their characteristic body pressure distribution.

Table 2 Results of principal component analysis (Eigen vector)

Variable name	Principal component 1	Principal component 2
Contact area	0.662	0.158
Total load	0.665	0.124
Variations of surface pressure	-0.1	0.938
Kurtosis	-0.331	0.282

Table 3 Results of principal component analysis (Eigen value)

	Eigen value	Contribution rate
Primary principal component	2.033	0.508
Second principal component	1.006	0.252

Table 4 Results of principal component analysis (Factor loading)

Variable name	Principal component 1	Principal component 2
Contact area	0.944	0.158
Total load	0.948	0.125
Variations of surface pressure	-0.142	0.941
Kurtosis	-0.473	0.283

Table 5 Verification results of difference of mean value

**1% significance
*5% significance

Males	US	Germany	France	Italy
Japan	**	**	**	**
U.S		**	**	**
Germany			—	—
France				—

Females	US	Germany	France	Italy
Japan	**	**	—	—
U.S		**	**	**
Germany			—	*
France				—

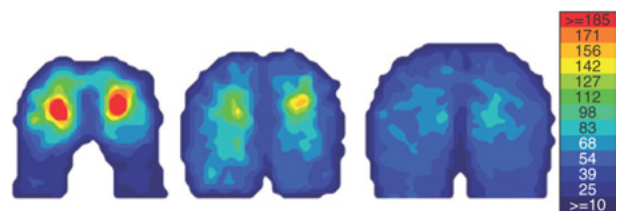


Fig. 2 Characteristics body pressure distribution

3.2. Buttocks Characteristics by Country

To confirm trend differences between countries, principal component analysis was carried out using all data for the four models. Figures 3 through 7 show the stratified distribution for each model. From the results of the principal component analysis in section 3.1, it was thought that the factor loading principal component 1 shown in Table 4 would express overall characteristics, representing size and that principal component 2 would express shape of the buttocks and its fleshiness. A characteristic of Japanese people's buttocks is that there is little variation in size, while there is large variation in shape and fleshiness of the buttocks.

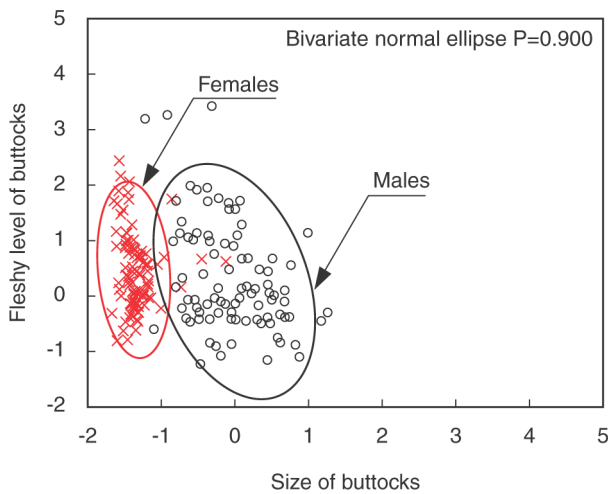


Fig. 3 Body pressure distribution of Japanese

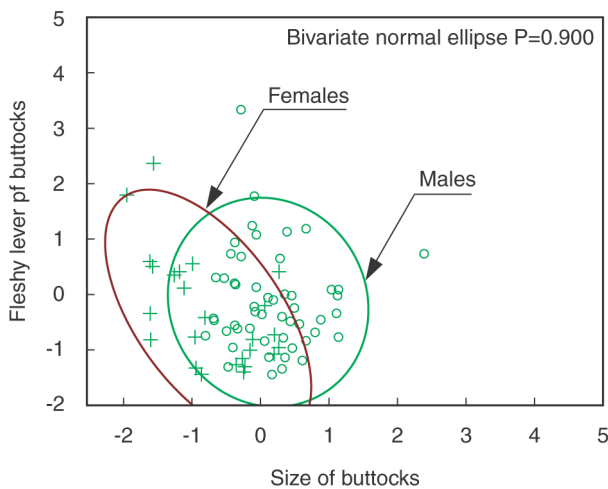


Fig. 4 Body pressure distribution of French

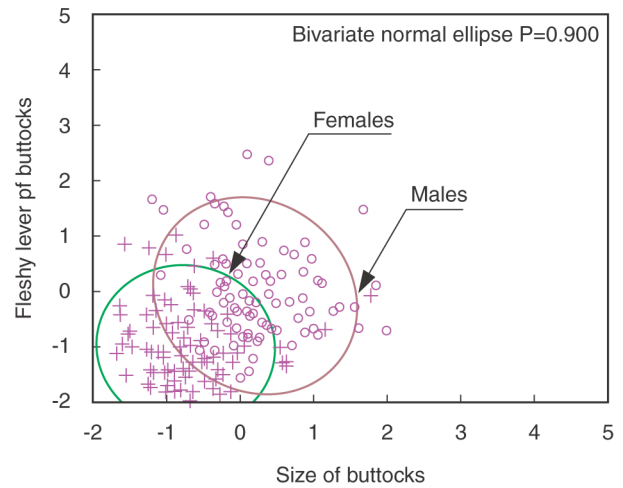


Fig. 5 Body pressure distribution of Italian

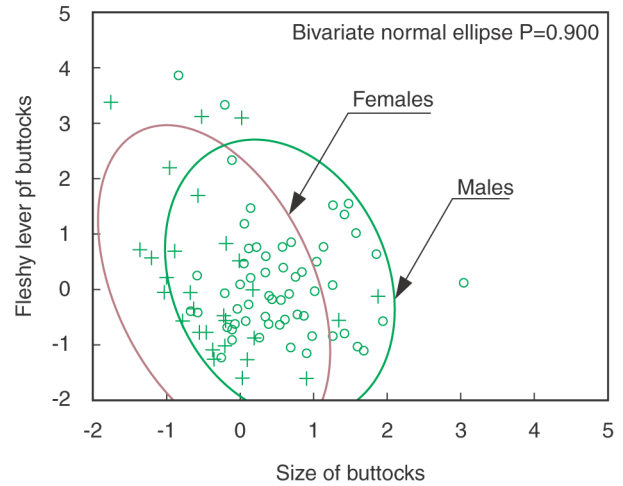


Fig. 6 Body pressure distribution of German

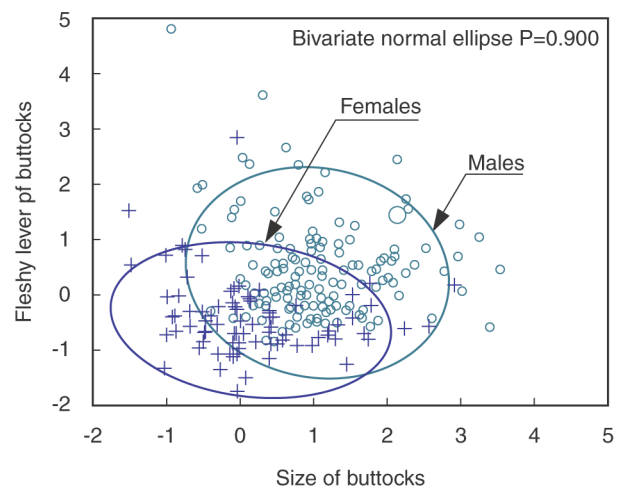


Fig. 7 Body pressure distribution of American

3.3. Creating a Standard Model for Measurements

From the fact described in section 3.2, the buttocks distribution and the average body pressure distribution are different by country, it is necessary to have a standard model for each country. In addition, because it cannot be said that the fit feeling evaluation is the same evaluation in each country, it is necessary to have a fit feeling prediction formula for each country. In this project, a model was created for standard measurement for an average Japanese male, in order to create a Japanese fit feeling prediction formula. Five test subjects were selected, close to the average of principal component 1 and principal component 2, as determined in section 3.2. Sizes of each part of their buttocks shown in Fig. 8 were compared with the average value, and the body pressure distribution closest to the average value shown in Fig. 9 was established as the target value for the standard measurement model. This model is shown in Fig. 10. It is composed of the pelvis and flesh. The hardness of the flesh was determined by measuring the buttocks hardness of ten Japanese males, selected at random, using a hardness gage.

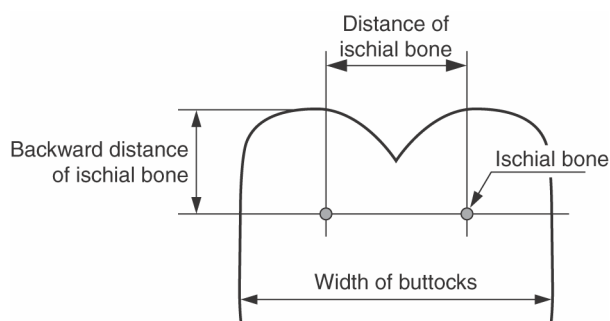


Fig. 8 Sizes of buttocks

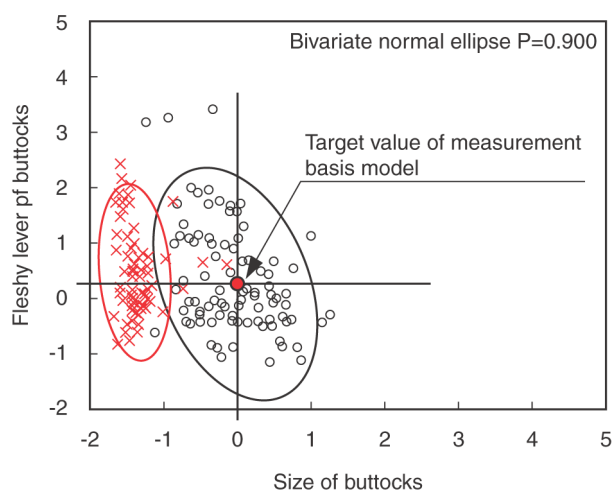


Fig. 9 Targeted value of measurement standard model

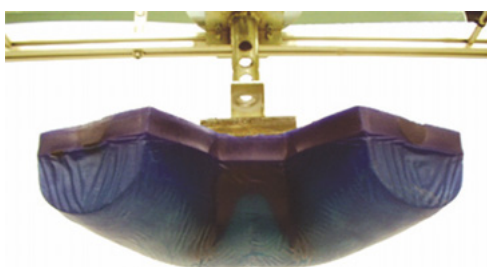


Fig. 10 Measurement standard model

Figure 11 shows the body pressure distribution of the test subjects when seated on the reference seat, and that of the standard measurement model. The contact area, the ischial bone peak value, distance of ischial bones, and backward distance of the ischial bone indicated by body pressure distribution are basically the same value.

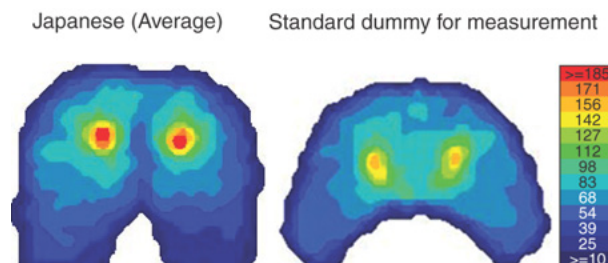


Fig. 11 Body pressure distribution at seated on reference seat

4. Formula to Predict Fit Feeling

4.1. Evaluation of Fit Feeling

The five test subjects, close to the average, determined in section 3.3 evaluated eight sample seats in different categories of motorcycle. They made a sensory evaluation of the fit feeling when in the static rider position, using the nine-point method as shown in Fig. 12. The results are given in Table 6. The sensory evaluation has a minimum score of 0.5 points, and from the analysis of variance shown in Table 7, variation of test subject scores were sufficiently small.

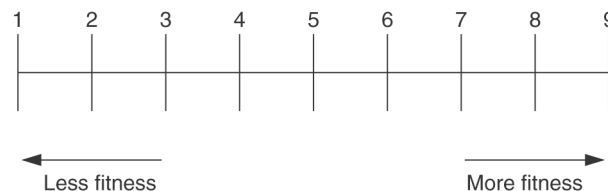


Fig. 12 Rating scale (Nine points method)

Table 6 Sensory evaluation results

Types of motorcycle	Score (Average)	Standard deviation
Touring	6.5	0.6
ATV	3	0.4
Large scooter	5.5	0.4
American	5	0.6
European "A"	3.75	0.6
European "B"	3.5	0.6
Small scooter	3	0.3
Off road	1.5	0.2

Table 7 Results of variance analysis

Factors	Sum of squares	Degree of freedom	Unbiased variance	Variance ratio	Verification
Test subject	3.78	4	0.94	2.29	
Sample	130.19	7	18.60	45.19	**
Error	11.53	28	0.41	—	
Summation	145.49	39	—	—	

**1% significance

4.2. Formula to Predict Fit Feeling

Using the standard measurement model, body pressure distribution for the eight sample seats were measured. Three body pressure distributions having different characteristics are shown in Fig. 13. The relationship between the results of the sensory evaluation in section 4.1 and the body pressure distribution data measured with the standard measurement model was subject to a multiple regression analysis, resulting in the fit feeling prediction formula (1). The relationship between the values predicted with this formula and the actual measurements is shown in Fig. 14. By substituting the measured values, it is now possible to predict fit feeling.

Fit Feeling = $\alpha_0 + \alpha_1 \times \text{Contact Area} - \alpha_2 \times \text{Ischial bone Peak Average}$ (1)

α_0 : Constant term

α_1 : Contact area coefficient

α_2 : Ischial bone peak average coefficient

($R^2 = 0.93$, Standard deviation of residual 0.4)

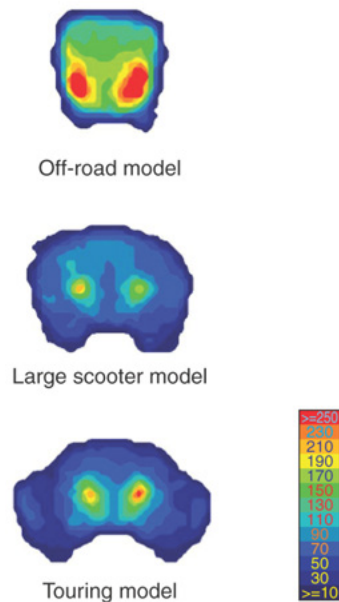


Fig. 13 Measured body pressure with measurement standard model

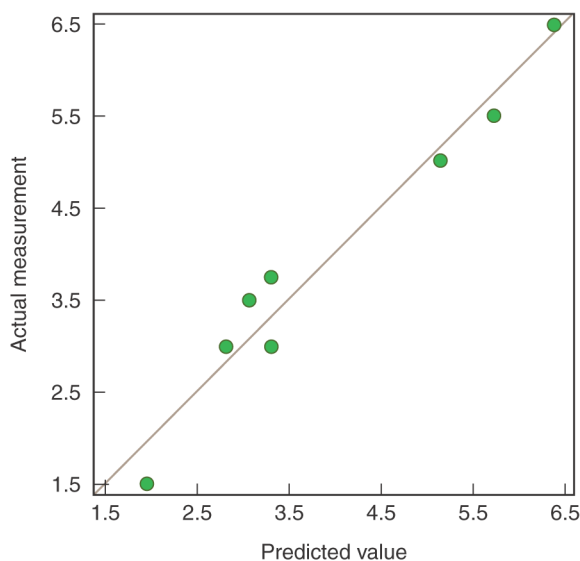


Fig. 14 Correlation between prediction score and sensory evaluation score

5. Creating a Body Pressure Distribution Simulation Method

The purpose of simulations is to make possible evaluations of the seat fit feeling at the design stage, thus enhancing the accuracy of the initial design. In order to make evaluations using the fit feeling prediction formula at the design stage, it is necessary to reproduce standard measurement model pressure distribution and contact area, at the same level as in the actual vehicle tests. As a method for actualizing this, a static implicit method that uses the finite element method was selected.

5.1. Analysis Software

In order to efficiently use the body pressure distribution simulation for standard measurement model, a general-purpose, nonlinear analysis software was selected, which serves the following functions.

- It must be able to accurately analyze the nonlinear characteristics of standard measurement model and seat contact area changes, major deformation of the buttocks, and material properties.
- Assuming an engineer with limited experience in analysis carries out this analysis as part of his/her routine work, it must have pre and post processor that makes possible easy creation of analysis data and processing of the necessary analysis results.

5.2. Mesh and Mesher Used

In this analysis, it is very important that contact and major deformation are able to be measured stably, and that the results obtained be the same as actual measurements. Considering this, the mesh consists of hexahedron elements. The mesher selected was one that can make highly accurate mesh, and for which one can freely specify the mesh size.

5.3. Analysis Model

In this analysis, the model is composed of the buttocks finite element model that can reproduce body pressure distribution equivalent to the standard measurement model, and the finite element model of the seat subject to analysis. To shorten the measurement period, half models were analyzed (Fig. 15).

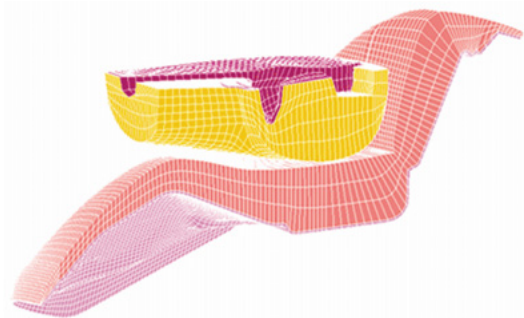


Fig. 15 Structure of analysis model

5.3.1. Buttocks finite element model

The pelvis and buttocks shape was made into 3D data through reverse engineering of the standard model shape, and the finite element model created (Fig. 16). This model is composed of muscle and fat, pelvis and thighbones. The detailed pelvis shape is reproduced using a surface. Deformation of the pelvis is not thought to be a large influence in this analysis, and was made rigid. The muscle and fat are given homogeneous characteristics, and the Mooney (binary format) Constitutive Material Law⁽²⁾ was applied to the extremely soft elastomer. The Mooney energy function is estimated by simulating a tensile test of the material making up the standard model (Fig. 17).

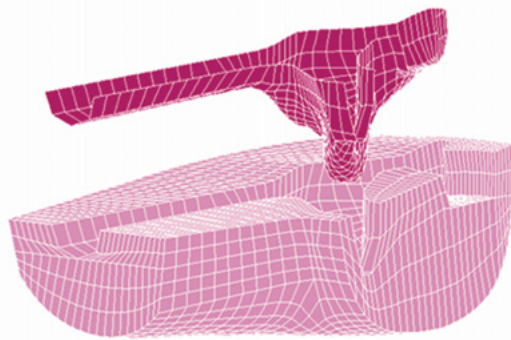


Fig. 16 FE model of buttocks

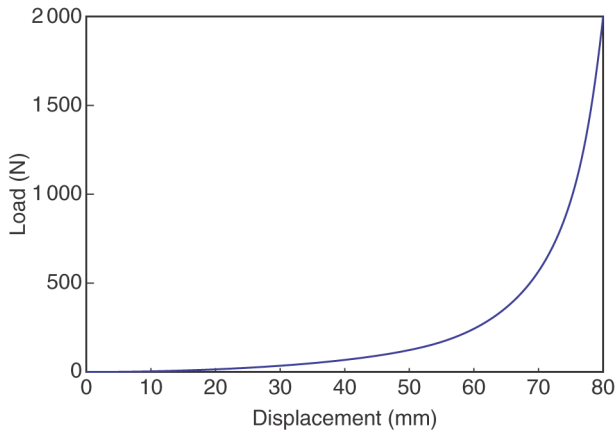


Fig. 17 Load-displacement characteristic of Mooney

5.3.2. Seat finite element model

For external data, the 3D model created for use in design is used, and it is composed of urethane parts and plastic seat bottom (Fig. 18). The urethane parts are modeled from the form material. The required material constant was determined by measuring the “stress-strain curve”, as shown in Fig. 19, in a single axis compression test. The seat bottom’s material characteristics are obtained based on measuring the “stress-strain curve”, as shown in Fig. 20, in the material tensile test using elastic-plastic material.

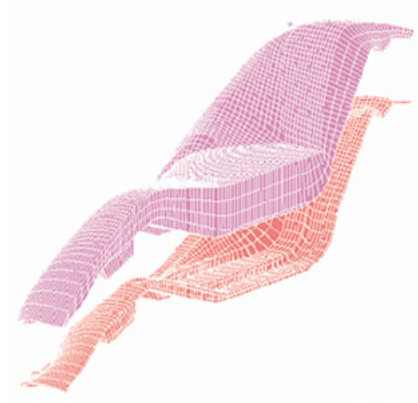


Fig. 18 FE model of seat

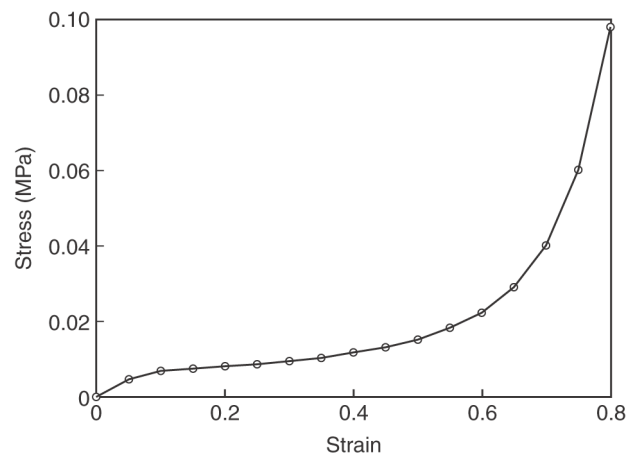


Fig. 19 Stress-strain curve of urethane

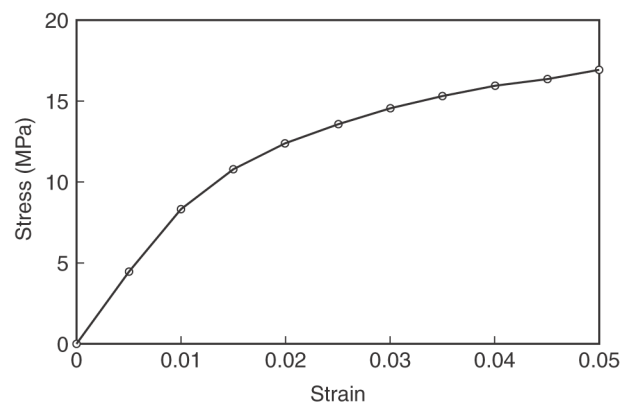


Fig. 20 Stress-strain curve of plastic

5.4. Analysis Results and Verification

5.4.1. Reference seat body pressure distribution simulation

The results of a simulation of sitting on the reference seat (500 mm × 500 mm × 50 mm urethane) confirmed that it is possible to reproduce well the standard measurement model contact surface shape and the pressure distribution (Fig. 21).

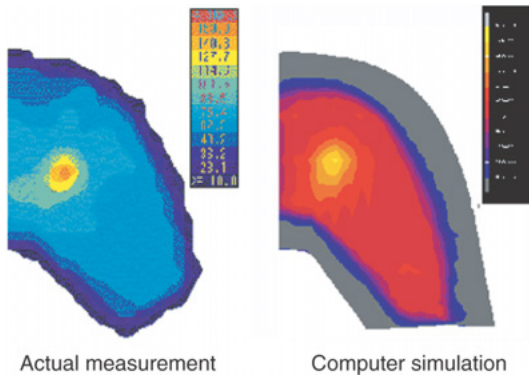


Fig. 21 Surface pressure distribution

5.4.2. Seat body pressure distribution simulation and fit feeling prediction

Simulations were carried out using motorcycle seats, with specifications that were changed in terms of urethane thickness, urethane hardness, and seat width. The results, as shown in Figs. 22, 23, and 24, confirmed a high correlation between simulated contact area, peak surface pressure, and fit feeling and the actual measurements of the above using the standard measurement model.

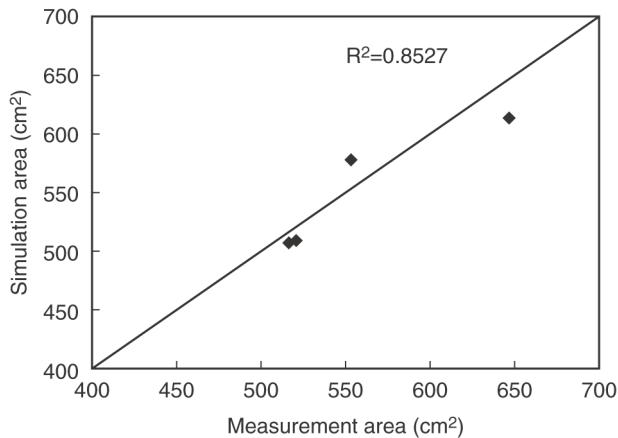


Fig. 22 Comparison of contact area between measurement and simulation

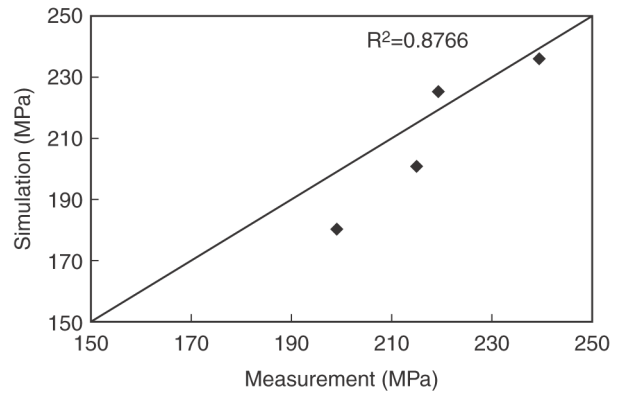


Fig. 23 Comparison of surface pressure of ischial bone peak between measurement and simulation

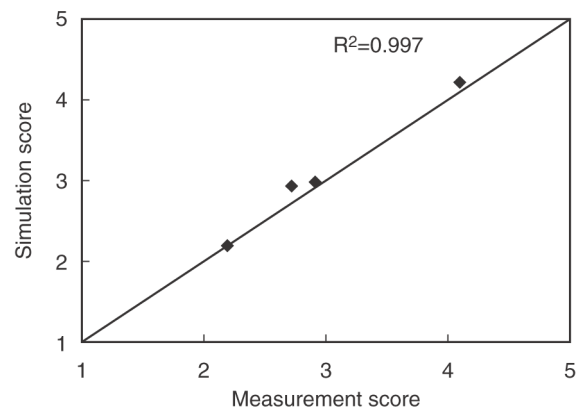


Fig. 24 Comparison of fitness feeling between measurement and simulation

6. Conclusion

- (1) From data concerning body pressure distribution when seated on a reference seat, it was possible to categorize a Japanese, German, Italian, French, and American model using the average size for each area, and to clarify the characteristics.
- (2) In order to accurately measure body pressure distribution data, a standard measurement model was created that is close to the average buttocks of Japanese males. Using the measurement data from this model, and the results of evaluation by average Japanese males, a fit feeling prediction formula was obtained.
- (3) To use the fit feeling prediction formula as a tool in the design stage, a simulation was established that uses the finite element method, and it is now possible to predict fit feeling at the design stage.

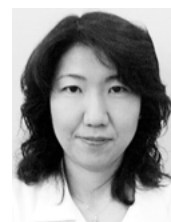
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