

Establishment of Evaluation Method for Riding Comfort of Motorcycle Seats

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ABSTRACT

To enhance the riding comfort of a motorcycle seat, a riding comfort evaluation tester that can reproduce the road vibration felt when the motorcycle is running was designed and fabricated. The riding sensation felt by the rider and the necessary seat vibration characteristics for a motorcycle were determined, and methods were established to enable evaluation of riding discomfort and the dynamic stroke feeling (the motion of the seat cushion, in response to impact from the road). In addition, a 3D mesh cushion made of thermoplastic elastomer, which has the reliable low-frequency vibration characteristics necessary for a motorcycle, was fabricated, and its riding comfort was compared to that of a conventional urethane foam cushion. As a result, it was clearly established that the 3D mesh cushion provides superior dynamic stroke feeling and riding comfort.

1. Introduction

In recent motorcycle development, enhancing the rider's ability to reach the ground and an increase in the number of parts located below the seat has limited the seat cushion thickness, creating concerns over a drop in riding comfort. On the other hand, enhanced riding comfort has a strong appeal for users, and demands are growing for improved performance in this area. New cushion materials that can provide the necessary motion for motorcycles must be developed in order to enhance riding comfort within the limits of seat cushion thickness. Therefore, a dynamic evaluation method that can clearly show the difference in riding comfort performance of the developed cushion materials is also necessary.

Previously, the conventional dynamic evaluation of seats has consisted of dropping dummy buttocks onto seats, or placing the dummy buttocks on seats and applying dynamic input from below to obtain the necessary parameters. In addition, seat dynamic states were measured during actual running, and the obtained parameters were analyzed together with sensory evaluation by rider during actual runs. However, each of these methods presented challenges that needed to be overcome when establishing a correlation with the sensory evaluation. The use of the dummy buttocks allowed

repeated measurement under the same conditions, so the parametric accuracy was high, but the evaluation conditions differed from those during actual running. Measuring dynamic seat states under the evaluation conditions allowed parameters to be obtained and sensory evaluation to be performed at the same time, but repeated measurement under precisely the same conditions also presented challenges, so accurate measurement values could not be obtained.

Making the measurement conditions as close as possible to those that exist during actual running was considered an effective means of overcoming these issues. Therefore, an attempt was made to establish a dynamic evaluation method by fabricating a motorcycle riding comfort evaluation tester that can both reproduce the input conditions during running and accurately measure data.

This paper describes the results of comparing a newly developed 3D mesh cushion made of thermoplastic elastomer (hereinafter referred to as "3D mesh cushion") with a conventional urethane foam cushion (hereinafter referred to as "foam cushion"), evaluating riding comfort according to frequency and establishing methods for evaluating the dynamic stroke feeling (the motion of the seat cushion in response to impact from the road) and riding discomfort.

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2. Vibration Characteristics During Actual Running of Motorcycle and Perception by Human Body

2.1. Vibration Characteristics when Riding a Motorcycle

In order to fabricate a riding comfort evaluation tester, longitudinal and vertical acceleration was measured at three locations on the motorcycle during runs at a specified speed on an evaluation road that simulated a public road (Road I). Acceleration was measured on the head pipe, the point at which the rider is seated, and the seat rail behind the passenger. The longitudinal and vertical acceleration was measured at each location. Figure 1 shows the measurement results for vertical acceleration during runs on the evaluation road by various vehicles. The results show that a large input is applied to motorcycles in the low frequency range of 1 to 3 Hz, at which motion of the seat cushion is easily felt. A riding comfort evaluation tester that was able to reproduce this characteristic acceleration was fabricated to dynamically measure and accurately evaluate motorcycle seats.

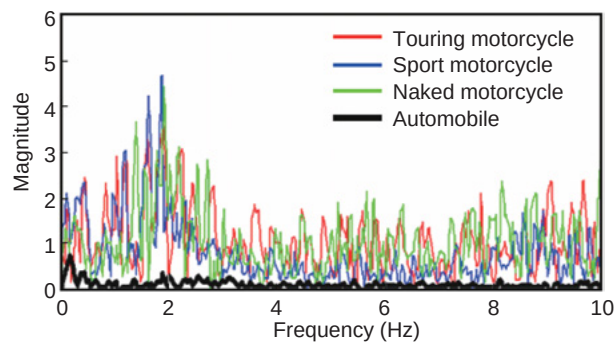


Fig. 1 Fourier spectra of acceleration in road I

2.2. Riding Comfort Evaluation Tester

The riding comfort evaluation tester is a three axis exciter⁽¹⁾ that can reproduce the vertical motions of the front and rear of the seat, and the longitudinal motion of the vehicle body, using acceleration data measured at three locations. Reproducing the motion at these three locations added a pitching motion and longitudinal motion to the vertical striking motion from below the seat. This enabled the buttocks of test subjects to reproduce complex pressing motions on the seat. An actual motorcycle seat, handlebars, foot rests, and a fuel tank were installed on the exciter table, and the seat was measured and evaluated with the test subjects sitting on the seat. Figure 2 shows the test equipment.

2.3. Perception of Motion of Seat Cushion and Sensitivity when Riding Motorcycle

The manner in which the rider experiences seat cushion motion when riding a motorcycle was investigated

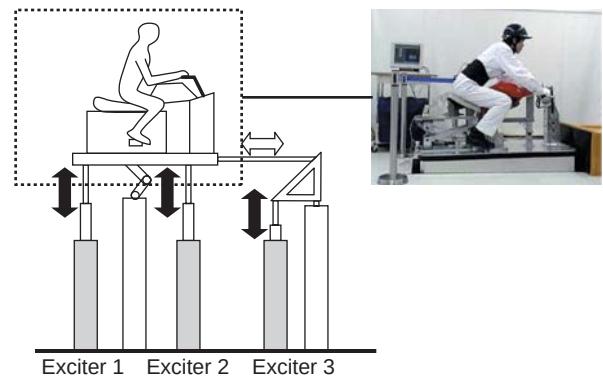


Fig. 2 Dynamic evaluation testing machine for motorcycles

Table 1 Vibration perception level on motorcycle

A: Insensitive to seat vibration

B: Sensitive to seat vibration

C: Indistinct seat vibration at resonating

1: Internal organ resonated

2: Upper body resonated

3: Head resonated

Frequency	Displacement mm	±5	±10	±20	±30	±40	±50
0.5	Hz	A	A	A	A	A	A
1		A	A	B	B	B	B
2		B	B	B	B1	C	C
3		B	B	B	C		
4		B1	B1	B1	C		
5		B1	B2	C	C		
6		B1	C2	C			
7		C2	C2	C			
8		C2	C2				
9		C3					
10		C3					

by having three test subjects with differing body weights ride the riding comfort tester and evaluate the feeling. Seat cushion motion is challenging to interpret in terms of riding comfort at frequencies of 20 Hz or more, so the evaluation range was set as 20 Hz or less. Table 1 shows the sensory evaluation results for the 0.5 to 10 Hz range, which exhibited a particularly large change in how riding comfort was perceived. These results show that riders are sensitive to motion of the motorcycle seat cushion over the range from 1 to 3 Hz, and that large motion of seat cushion in this range was felt to provide excellent riding comfort with a good dynamic stroke feeling. In the 4 to 8 Hz range the seat stroke was not able to be felt as strongly, and the motion of the seat cushion became a source of discomfort to the rider. The large motion of the seat cushion in this range resonated throughout the riders' internal organs and upper body, and was felt as an unpleasant rough vibration. Therefore, it was felt that minimizing the motion of the seat cushion in this range was better for riding comfort. These results indicated that providing appropriate motion in the low frequency range of 1 to 3 Hz and suppressing motion of the seat cushion in the 4 to 20 Hz range are important for enhancing motorcycle riding comfort.

3. Dynamic Performance Evaluation Method

3.1. Evaluation of Dynamic Stroke Feeling

The method investigated as a way to dynamically evaluate seat cushion characteristics consisted of fixing a seat on a jig, dropping dummy buttocks, and measuring the seat cushion displacement when the dummy buttocks struck the seat (Fig. 3). The total of a, b, and c in Fig.3 was obtained as the displacement that expresses the dynamic stroke feeling, or the amount of motion of the seat cushion in response to shocks from road. Sensory evaluation of the dynamic stroke feeling was performed by locating a suitable road surface allowing low frequency from 1 to 3 Hz (Road II), and performing an evaluation according to the scale given in Table 2. Figure 4 shows the correlation between the total of displacements a, b, and c and the sensory evaluation. A somewhat weak correlation was confirmed, but it is not sufficient for

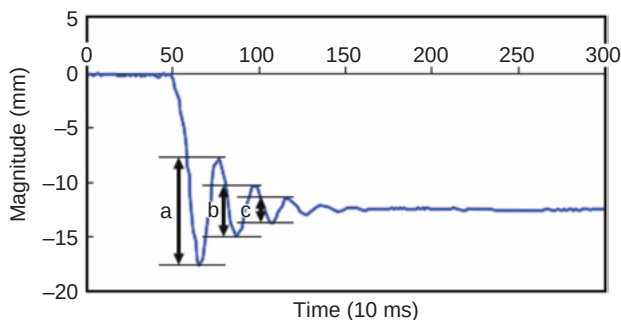


Fig. 3 Displacement data in dummy hip drop test

Table 2 Evaluation scale for dynamic stroke feeling

Score	Definitions
5	Extreme feeling
4	Fair feeling
3	Moderate feeling
2	Somewhat felt
1	Slight feeling

practical use.

The displacements that represent the dynamic stroke feeling on the newly developed riding comfort evaluation tester were investigated as follows. A motorcycle was run over the Road II to evaluate dynamic stroke feeling, and the data from accelerometers attached to the chassis in three locations was measured. The acceleration at these three locations was reproduced on the riding comfort evaluation tester, and vertical acceleration of the seat was measured with test subjects weighing 70 kg riding the tester, and the displacement of the seat cushion was calculated (Fig. 5). Sensory evaluation was performed at

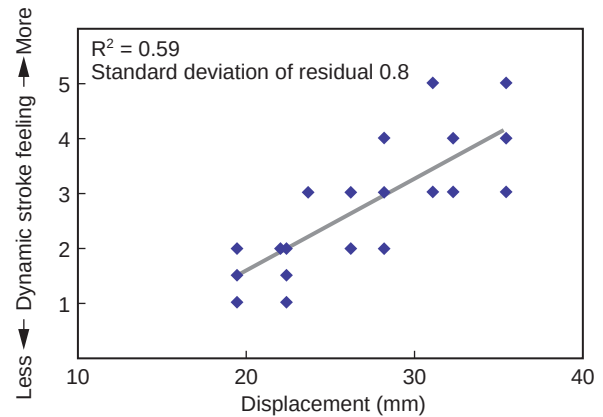


Fig. 4 Relationship between total displacement of dummy hip drop test and dynamic stroke feeling

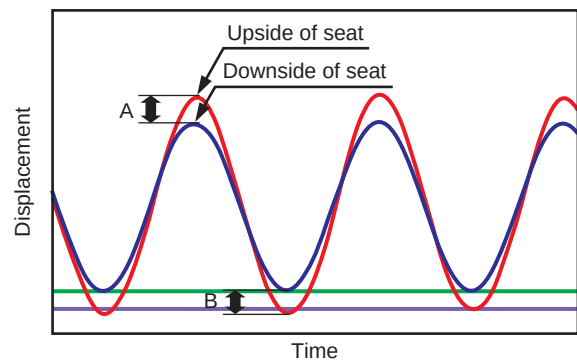


Fig. 5 Displacement data in road II

the same time, and three test subjects each weighing 70 kg evaluated the dynamic stroke feeling according to the scale given in Table 2. The parametric analysis was limited to the low frequency range of 1 to 3 Hz, data sections suitable for analysis were extracted, and parameters such as the total displacement and phase difference were obtained. The correlation between these parameters and the sensory evaluation results was highest for the total of displacements A and B, shown in Fig. 5. Figure 6 shows the relationship between the total of displacements A and B and the dynamic stroke feeling. The total of displacements A and B and the dynamic stroke feeling exhibit a high correlation, and it can be inferred that the test subjects are evaluating the difference in seat cushion motion relative to the input under these conditions.

3.2. Riding Discomfort Evaluation Method

The parameters that represent riding discomfort on the riding comfort evaluation tester were investigated as follows. A motorcycle was run over a road that easily produces unpleasant vibrations (Road III), and the data from accelerometers attached to the chassis in three locations was measured to evaluate the range of riding discomfort. The acceleration at these three locations was reproduced on the riding comfort evaluation tester, and vertical accelerations of the upside and downside of the seat were measured with test subjects weighing 70 kg riding the tester. Sensory evaluation was performed at the same time, and three test subjects, each weighing 70 kg, evaluated the dynamic stroke feeling according to the scale given in Table 3. Degree of riding discomfort is determined by evaluating a wide of range of frequencies felt by the human body, so the magnification factor for the 5 to 20 Hz range was obtained, and the magnification factor tendencies were compared for various seat cushion materials (Fig. 7). The magnification factors differ somewhat, but they exhibit similar tendencies at each

Table 3 Evaluation scale for dynamic comfort quality

Score	Definitions
5	Very comfortable
4	Slightly comfortable
3	Acceptable
2	Slightly uncomfortable
1	Very uncomfortable

frequency. Therefore, area S, the integration value of the magnification factor for the 5 to 20 Hz range, was used as the parameter expressing the riding discomfort evaluation. This parameter is expressed as an area, raising the issue that magnitude of the magnification factor becomes an average. However, the results shown in Fig. 8 confirm that there is sufficient correlation between sensory evaluation and magnification factor area S, so it was judged that this parameter can accurately express riding discomfort.

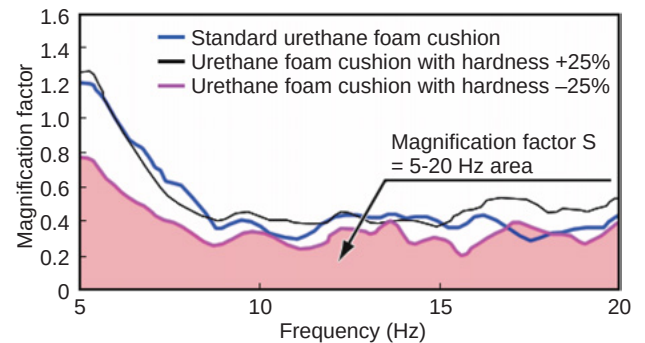


Fig. 7 Magnification factor in road III

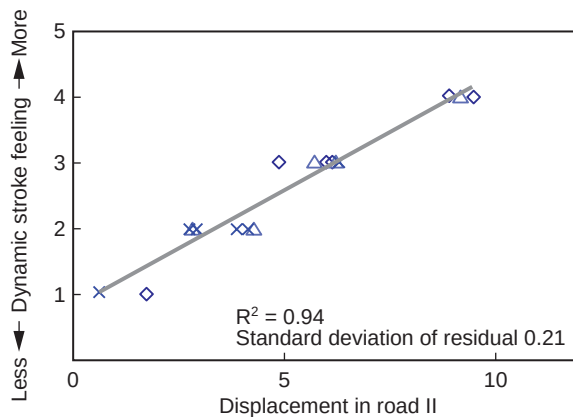


Fig. 6 Relationship between displacement and dynamic stroke feeling in road II

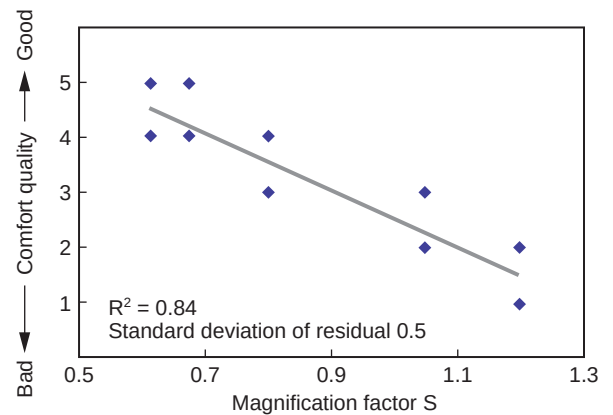


Fig. 8 Relationship between magnification factor S and comfort quality in road III

4. Comparison of 3D Mesh Cushion and Foam Cushion Performance

4.1. 3D Mesh Cushion Characteristics

The cushioning characteristics of cushion materials change according to the combination of materials and their density, so it is important to determine the proper cushion characteristics in accordance with the concept of a motorcycle. Decreasing the hardness of conventional foam cushions can produce low frequency motion, but these characteristics are not maintained over long-term use. The foam cushion loses its resiliency, which has significant adverse effects, such as an unchanging body pressure distribution. This makes it necessary to make the cushion so hard that it provides insufficient motion at low frequencies. The low rebound materials used in recent years provide superior shock absorption and body pressure dispersion, but when subjected to a load, these materials lose resiliency and are unable to produce the seat cushion motion necessary for motorcycles. The 3D mesh cushion that was the focus of this study uses thermoplastic elastomer materials, and diverse cushion characteristics can be set by changing the material, density, wire diameter, intermingling point density, and other factors. The residual strain in compression under high temperatures and repeated hardness changes, which have been weak points for thermoplastic elastomers, were modified for this newly developed 3D mesh cushion, and the material specifications were set to realize the required characteristics. Test pieces of the same size and hardness, without the seat fabric, were fabricated from conventional foam cushion and the newly developed 3D mesh cushion, to investigate the ability of the 3D mesh cushion to enhance the dynamic stroke feeling. The vibration characteristics of these test pieces were measured in conformity with JASO B 407-87; the test results are shown in Table 4. The 3D mesh cushion has a lower resonance frequency and a higher magnification factor, and exhibits similar effects to decreasing the hardness of the conventional foam cushion. Therefore, it was assumed that the 3D mesh cushion can provide a superior dynamic stroke feeling while maintaining the same hardness as the foam cushion.

4.2. Evaluation Results of Dynamic Stroke Feeling

In the following experiment, a 3D mesh cushion with a foam cushion upper layer was compared with a conventional foam cushion having the same upper surface shape. Figure 9 shows the structural diagram.

The riding comfort evaluation tester was used to quantitatively evaluate the dynamic stroke feeling enhancement effects of the 3D mesh cushion by reproducing the accelerations measured in test runs on Road I (see Section 3.1) and measuring the total of displacements A and B. Figure 10 shows the results of comparing the total of displacements A and B for the 3D

Table 4 Characteristics of vibration by test piece

	Foam cushion	3D mesh cushion
Resonance frequency (Hz)	6.10	5.41
Magnification factor of resonance	3.82	4.62

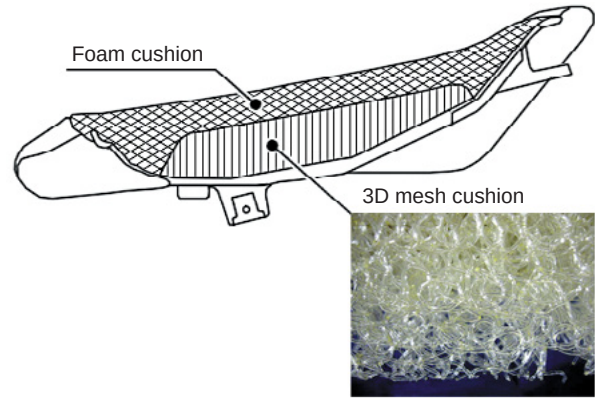


Fig. 9 Structure of new seat with 3D mesh cushion

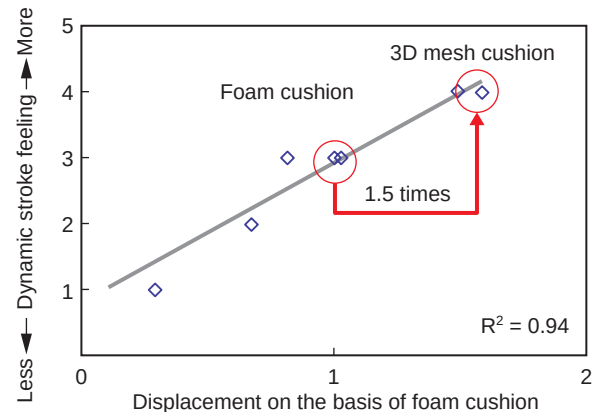


Fig. 10 Relationship between displacement and dynamic stroke feeling

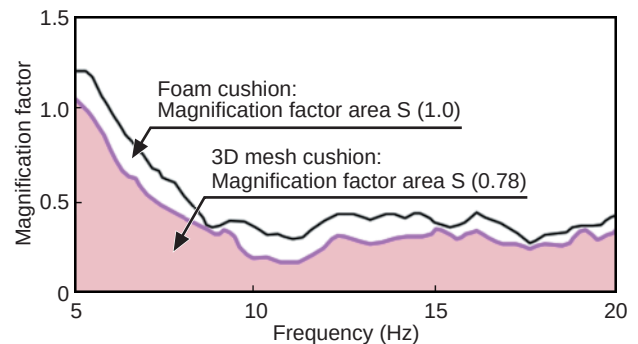


Fig. 11 Magnification factor of 3D mesh cushion and foam cushion in road III

Table 5 Verification results of dynamic stroke feeling and discomfort evaluations in actual driving

Dynamic stroke feeling evaluation

	Expectancy	Actual measurement	Residual
3D mesh cushion	4.2	4.0	0.2
Foam cushion	3.5	3.7	-0.2

Discomfort evaluation

	Expectancy	Actual measurement	Residual
3D mesh cushion	3.9	4.2	-0.3
Foam cushion	2.9	3.3	-0.4

* Displacement: bench mark is foam cushion

* Magnification factor S: bench mark is foam cushion

mesh and foam cushions. Here, the displacement for the 3D mesh cushion was confirmed to be 1.5 times that of the foam cushion. This indicates that the 3D mesh cushion provides a noticeable enhancement in the dynamic stroke feeling, and that the material specifications are appropriate.

4.3. Evaluation Results of Riding Discomfort

The riding comfort enhancement effects of the 3D mesh cushion were quantitatively evaluated by using the riding comfort evaluation tester to reproduce an uncomfortable road vibration as described in Section 3.2, measuring the seat vertical acceleration, and obtaining magnification factor area S. Figure 11 shows that the magnification factor area S of the 3D mesh cushion is 22% less than that of the foam cushion, which clearly establishes that the 3D mesh cushion effectively reduces riding discomfort.

5. Verification Results by Actual Running

The dynamic stroke feeling and riding discomfort evaluation results obtained using the riding comfort evaluation tester were verified by having three test subjects ride motorcycles on Road III to evaluate the dynamic stroke feeling and riding discomfort experienced with the two types of cushions. Past experimental results⁽²⁾ showed that the variance in sensory evaluation was approximately 0.3 to 0.7 points, so the expected value target was set within ± 0.5 points or less; Table 5 shows the expected values and measured values (test subject average values) for the 3D mesh cushion and foam cushion. The residual was within ± 0.5 points, which confirmed that this is a valid method of evaluating dynamic stroke feeling and riding discomfort.

6. Conclusion

A dynamic seat evaluation method using a motorcycle riding comfort evaluation tester was established, and the

difference in performance between a 3D mesh cushion and foam cushion was clarified quantitatively.

- (1) A riding comfort evaluation tester was used to establish a riding comfort evaluation method that divides the evaluation into the dynamic stroke feeling domain and riding discomfort domain.
- (2) A motorcycle riding comfort evaluation tester was used to find the low frequency motion of seat cushion necessary when riding a motorcycle. This enabled the development of a 3D mesh cushion of thermoplastic elastomer that provides a superior dynamic stroke feeling.
- (3) It was clearly established that the newly developed 3D mesh cushion increases displacement, which represents the dynamic stroke feeling, by 1.5 times and reduces the magnification factor area, which represents riding discomfort, by 22%, compared to the foam cushion.

Acknowledgements

The authors wish to express their deep thanks to everyone at NHK Spring Co., Ltd. for their immense cooperation with this development project.

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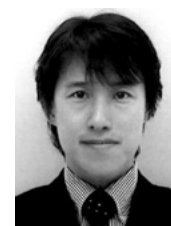
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