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A Study on Automotive Seat Cushions having Multi-hardness Distribution for the Elderly

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Abstract

Objectives: Recent trends show an increase in driving by the elderly and most of them drive with a poor posture. In this study, not only the tests for body pressure but also the tests to identify characteristics of the seat itself were conducted. **Methods/Statistical Analysis:** Static load tests were conducted first to derive the seat-inherent characteristics such as deflection and hardness, etc. of the seat cushion as a function of loads for the automotive seat, and measurement tests for body pressure were conducted to secure body pressure data of the elderly. Combining the above two test results, final hardness values were obtained through which seat cushion pattern models having 8-hardness distributions could be derived. **Findings**: As a result, curves and functional equation for the two variables were derived through deflection as a function of measured loads. Also, hardness values at each point of the cushion could be found from the slopes of the curves mentioned, with the appearance of the phenomenon where the slope showed a steep increase in a particular region. This was affirmed to have occurred due to a difference in thicknesses of the cushion. Secondly, concentrated regions of body pressure per subject were affirmed and analyzed in the body pressure tests. By combining two test results, a total of 11 seat cushion pattern models could be derived, of which pattern analyses were conducted for 3 types observed with many personnel. **Improvements/Applications**: When the cushions are produced on the basis of the above pattern, it is considered possible to more ideally distribute the weight and to improve comfort upon seating compared with the commercial cushions.

Keywords: Body Pressure, Deflection, Hardness, Pattern, Seat Cushion

1. Introduction

Studies of the past were engrossed only in development of the performance and technology of automobiles. However, today's studies on automobiles also place a large importance in searching for methods that can maximize passengers' structural safety and sensitivity, with relevant studies[1–5] under way. In addition, with an increase in the average human life expectancy, this has also brought about an aging society. For such reasons, a large importance must also be placed on the studies of automobiles for the object of the elderly. Currently, most of the elderly are seated on the seat cushion with degradation of body structure and functions. So as to frequently drive with an unsatisfactory posture upon driving. Such unsatisfactory postures of the elderly induce blood circulatory

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disturbances and pain. Worsening of these can lead to diseases such as pressure sores, etc. Also[6], the seat cushion should ideally distribute body weight, and properly absorb impacts and vibrations. However[7], the elderly who are prone to poor seating postures, fail to obtain such condition so that comfort is remarkably degraded, sometimes accompanied by the appeal of pain upon driving for a long time. To solve such problems as above, various studies are being conducted where the seating posture types preferred by drivers and the characteristics of body pressure distribution are analyzed and standardized. In [8] has made quantitative measurements for a classification of the postures preferred by drivers and the types of body pressure distribution. Then, the effects of drivers' gender, body size and Occupant Package Layout (OPL) conditions on seating strategy were analyzed. Up to now, studies with classification of driving postures preferred by drivers and the types of body pressure distribution have been conducted. However, accuracies of the results of the above studies have been determined somewhat insufficient. The reason is that measurements and analyses of body pressure distribution were conducted without identification of the characteristics of load and deflection, etc. of the seat itself which was most basic. Also, studies on automotive seat cushions have been conducted for objects of the general public thus far. However, studies on seat cushions for objects of the elderly were identified to have not been conducted. Thus, in this study static load tests were conducted first to derive the seat-inherent characteristics such as deflection and hardness, etc. of the seat cushion as a function of loads for the automotive seat, and then measurement tests for body pressure distribution were conducted to secure body pressure data of the elderly. Based on the data combining the above two test results, final hardness values were obtained through which seat cushion pattern models having 8-hardness distributions could be derived. When the seat cushions are produced on the basis of the above pattern models, it is considered possible to more ideally distribute the body weight and to improve comfort upon seating compared with the existing commercial cushions.

2. Configuration of Test and Method

2.1 Static Load Test

The seat employed in the present tests is the power seat for the driver applied to sedan-class vehicles of Korean finished automobiles. To derive deflection characteristics as a function of loads of the present seat together with hardness values, static load tests were conducted. Upon

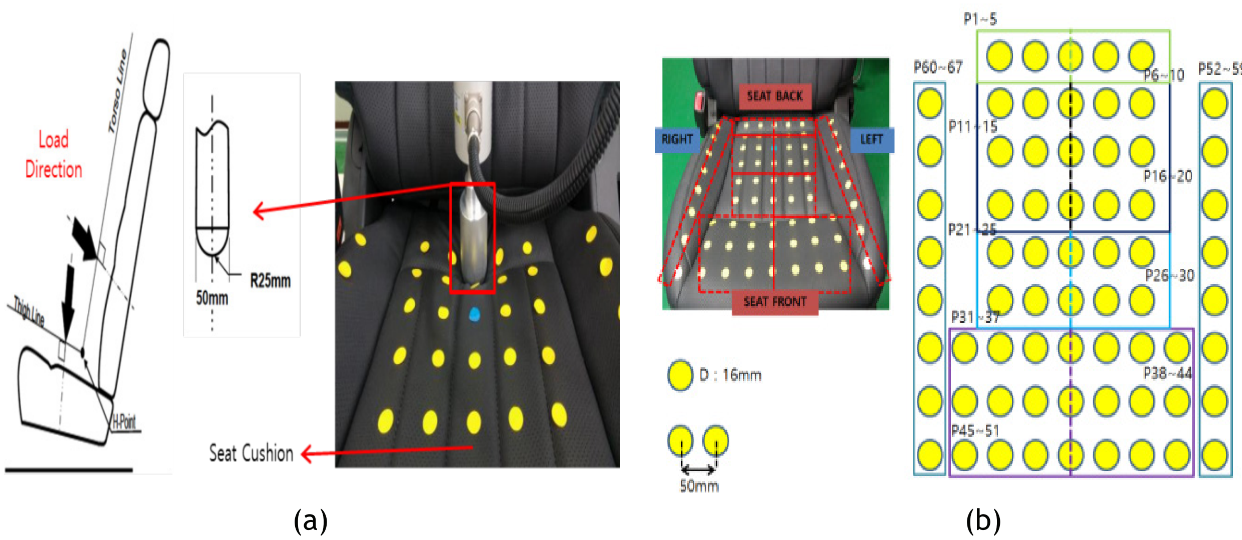


Figure 1. Static load test (a) Configuration of test (b) Load point.

tests, a motor vehicle seat comfort performance measures spec[9] was utilized for implementation, with the test methods being as follows. The seat was placed on a test jig set, and the indenter as the apparatus for pressurizing the seat cushion was vertically positioned as shown in Figure 1 and fixed to make it immobile. The indenter employed for the tests had a diameter of 50mm. As shown in the figure, the tip of the indenter had a spherical shape. Moving speed of the indenter was set at 200mm/min. Loading began in the state of pressurization at 0.5N, with subsequently pressurization up to 200N.

Yellow circles in Figure 1(b) show the points for application of load to the seat cushion by using the indenter. Direction of the seat was divided into Left and Right with reference to the front face being faced at when the driver was seated on the seat. The total number of points for application of the load was 67 ea. Tests were implemented with the interval between points of 50mm being separately marked on the seat.

2.2 Body Pressure Test

Body pressure was measured at the place where the hip among the body parts of a human come into contact with the seat cushion when the driver was seated. The present tests were conducted in a static state rather than in actual running of the vehicle. For such reasons, the dimension of the actual automobile was measured, based on which similar test apparatuses were designed and independently produced. This is shown in Figure 2 (a). Subjects of the present tests were the elderly aged beyond their 60's, and personnel who were currently driving or had driving experience, were selected for implementation. The total number of subjects participating in the test was 42 people, with the test methods being implemented by utilization of a motor vehicle seat comfort performance measures spec. The content was as follows. Each subject recorded body information such as height, gender, body weight, etc. in the data survey chart before being seated. Next, the subject was made to be seated on the seat with a body pressure distribution mat installed. The above measuring equipment was XSENSOR technology corporation PX100, Canada with a total of 2,304 sensors embedded in the mat. Tests involved the method where pressures of the cell with the mat being in contact with the body part upon seating of the subject were measured and transmitted in real time to allow checking. Angle for the backrest was fixed at 100° upon testing. Also, by enabling the seat to slide as the control apparatus for the front/rear length of the seat, the most comfortable seating posture was allowed to be taken. While the subject was in the state of being seated, two arms were made to lightly hold with both arms stretched out, with the right foot made to be

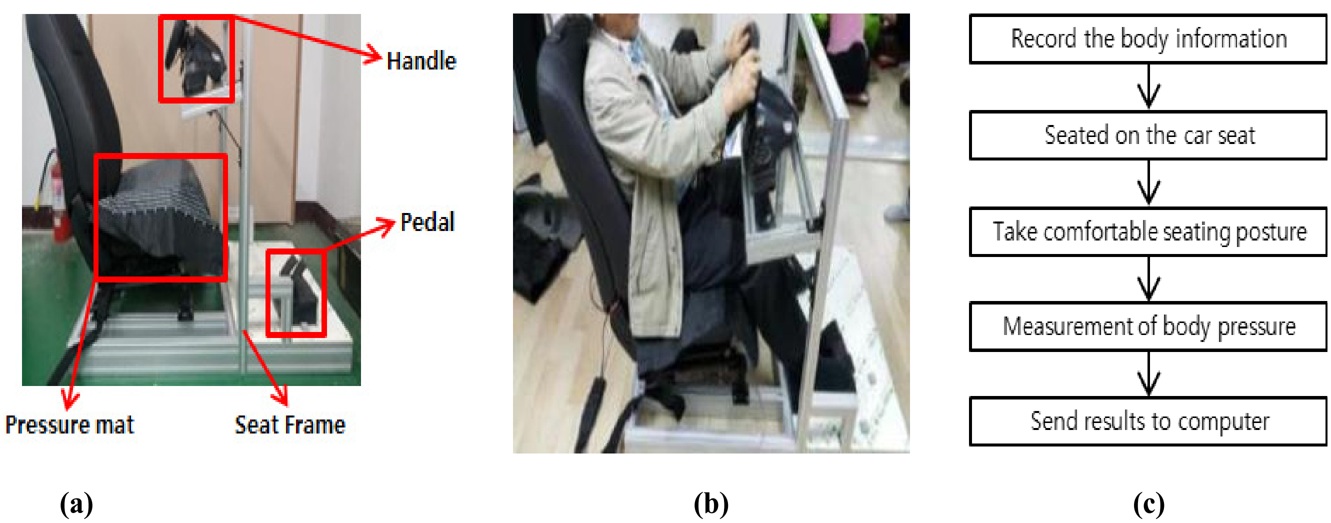


Figure 2. Body pressure test (a) Configuration of test (b) Measure the pressure (c) Diagram.

placed on the acceleration pedal and the left foot put down. Measurement of body pressures was started when the subject took the seating posture. Measurement of body pressures was started in the stabilized state of body pressure and continued for 1 minute for each subject. Appearance of the subject during measurement of body pressures is shown in Figure 2(b)and a schematic diagram for the test is shown in Figure 2 (c).

3. Test Results and Analysis

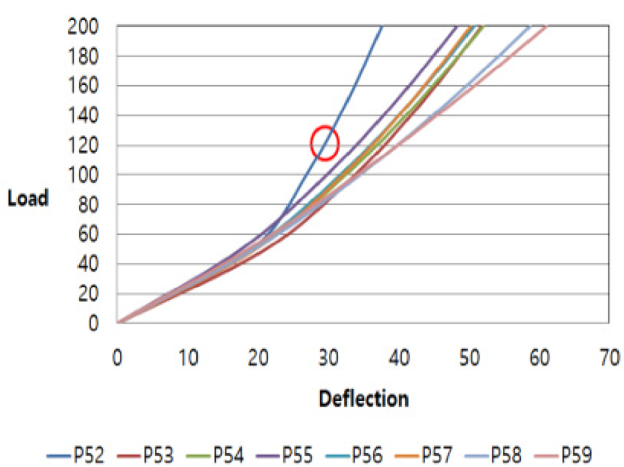
3.1 Static Load Test

Functional equation was derived through deflection of the seat cushion as a function of loads measured in the present test. Through the functional equation, hardness values at each point of the seat cushion could be found from the slopes. Functional equation at each point will be applied to the data of body pressure distribution later. The Figure 3 shows the representative two types among graphs represented by the functions derived per section. The graph was shown for deflection values of the seat cushion when the loads were 0, 50, 100, 150, and 200N. In the graph of the Figure 3 (a) showing the results from Point 52 through Point 67 displayed Figure 1(b), the slopes were observed to be relatively similar. However, only the slope in P52 as the region displayed by a red circle was affirmed to show a steep increase. In the graph of the Figure 3 (b) showing the results from Point 67 through Point 67 displayed Figure 1 (b), the same phenomenon as that for P67 was observed in a similar fashion.

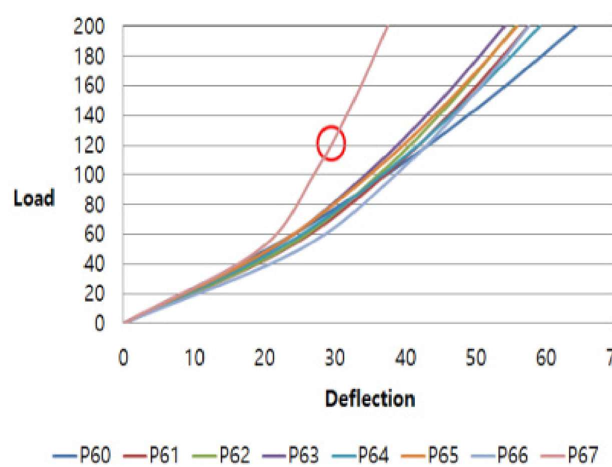
The above phenomenon was analyzed to have occurred due to thickness differences in each region of the seat cushion. According to the results of measuring thicknesses of each region, the thickness at the center part of the cushion was measured to be the largest at 66.6mm. On the contrary, the thickness of the end region of bolster was measured to be the smallest at 24.6mm. This as in agreement with the region where the slope values showed a sudden increase upon static load tests. Based on this observation, the thickness of the seat cushion was also affirmed to be a factor which could affect hardness values.

3.2 Body Pressure Test

According to the results of tests, the appearance at the point where the mat was in contact with the body could be affirmed as shown in Figure 4. Also, the region where pressure values are shown to be high is represented by red color, whereas the region of low pressure values is represented by blue color. Through this observation, concentration status of body pressures could be identified. The place displayed by a red circle in Figure 4 (b)



(a)



(b)

Figure 3. Load vs deflection curve (a) Point 52 to 59 result (b) Point 60 to 67 results.

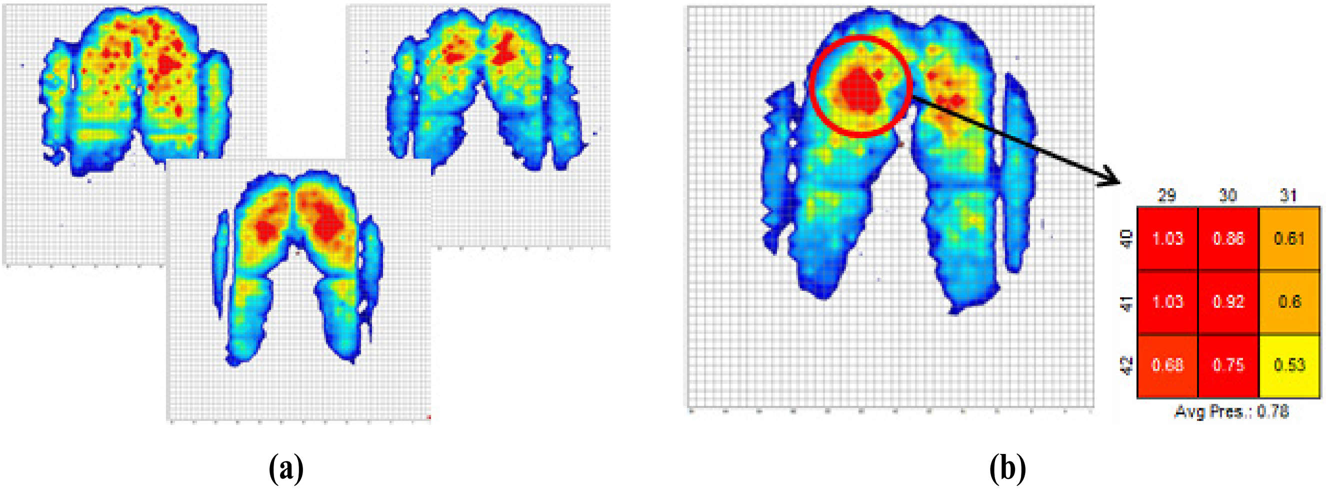


Figure 4. Result of body pressure test (a) Test figures (b) Concentration of body pressure.

is the region where concentration of body pressures occurred. Also, pressure values in the relevant region as well as average pressure values could be affirmed. As a result of the present tests, such simple analysis could be conducted. However, there was a limitation in derivation of patterns by application of the results of the static load tests conducted earlier and of the present tests. Thus, a more precise analysis was conducted by using a separate analysis method upon derivation of pattern models, the contents of which are described in the next chapter.

3.3 Derive a Hardness Pattern Model

As the first method to derive a hardness pattern model, the test results for body pressures were classified per seating posture type. The posture types were classified into 3 types including posture biased toward the left, posture

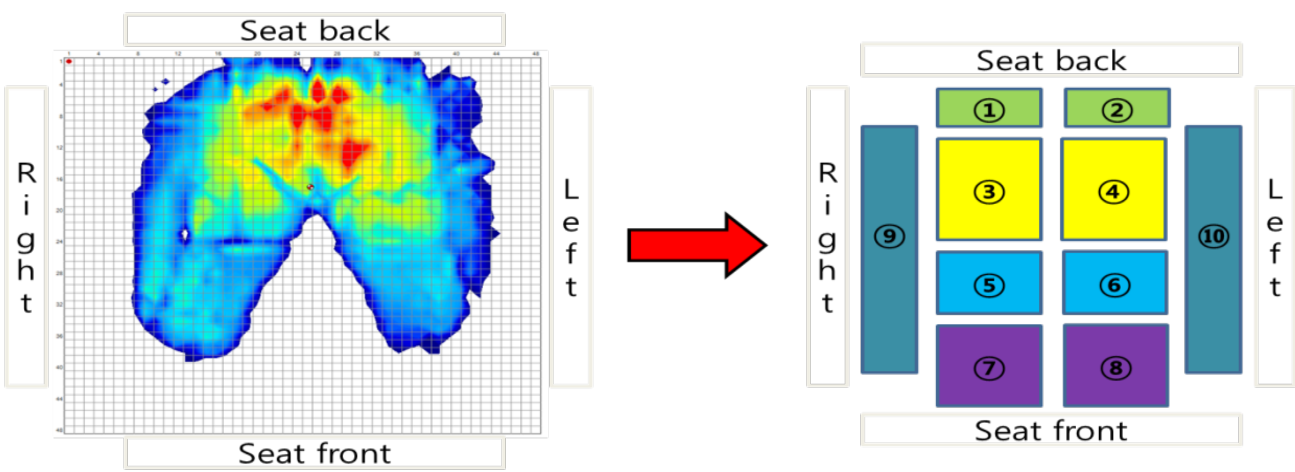
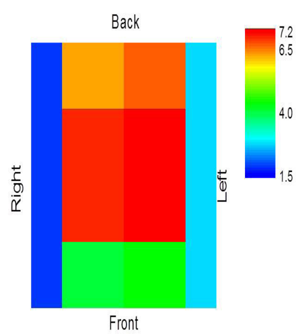
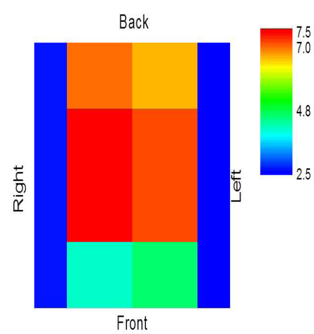
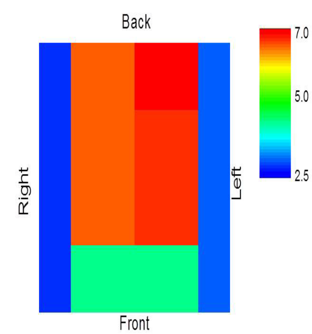
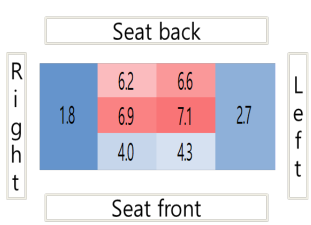
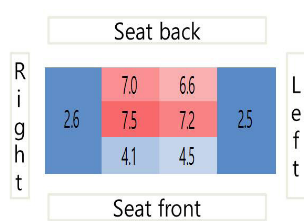
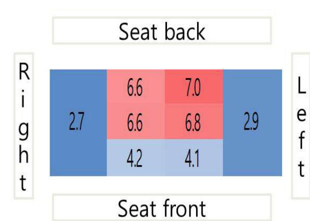


Figure 5. Division of the body pressure section.

biased toward the right, and standard posture with the left and right being even. Here, Body Pressure Ratio(BPR) was used. For calculation of BPR, classification of the regions for body pressure distribution was required. Accordingly, the sections of the seat cushion were divided into a total of 10 sections according to the body part of the actual contact as shown in Figure 5. □ and □ as the section where the tip part of the hip is in contact, □ through □ as the section where the front through to the rear part of the hip is in contact, □ and □ as the section where the thigh is in contact, and □ and □ as the section where the bolster is in contact. This division was made by considering shape of the seat cushion and variables which could affect body pressure distribution upon seating of the subject.

Excessive body pressures of drivers upon seating on the seat occur at the part of tuberosity of ischium of the hip. According to the test results, the above phenomenon occurred commonly for all subjects. Based on this observation, the positions where body pressures were concentrated were divided with reference to □ through □ regions displayed in Figure 5. As a result, the type with high body pressures on the left was shown for 26 people, the type with high body pressures on the right for 9 people, and the type with similar body pressures on the left and the right for 7 people. Even in the case of belonging to the same type, the positions for concentration of body pressures are shown to vary in the regions excluding □ through □ regions. That is why all concentrated positions in the remaining regions should also be considered when the pattern models are derived. As the second method to derive patterns, the body pressure values observed at each point of Figure 1. (b) were multiplied by the area values accounted for by the cell of body pressure distribution

Table 1. 8-Hardness pattern model

Pattern model number	**No. 1**	**No. 2**	**No. 3**
Shape of pattern			
Hardness value			

mat for the calculation of loads. And then the above load values were substituted for functional equation of each point derived by static load tests. Through substitution of load values, hardness values and displacement values as a function of loads were obtained inversely. However, in □ through □ regions where the tip of the hip was in contact, the hardness values were measured to be lower than the average value for all subjects. Hence, the hardness values were assumed to be the same as those for □ through □ regions upon calculation of hardness values. Consequently, the final pattern models were made to become 8 regions. By using hardness values recalculated per region, a total of 11 ea. of 8-hardness pattern models were derived. Among these, the pattern models where the number of personnel was observed to be small were excluded from the result. Three types of 8-hardness pattern models which were observed for a large number of personnel along with the hardness values are shown in the Table 1.

No.1 pattern model showed the hardness for the overall region could be seen to be higher for the left side, hip as well as in all regions, including bolster and is the pattern observed for the largest number of personnel of 9 people. No. 2 pattern model is the pattern where the closest values were observed when the sums of ratios for □ through □ regions displayed in the Figure were compared between the left side and the right side, and is the pattern observed for the second largest number of personnel of 7 people. While No. 3 pattern model showed a higher hardness for □ region as the right side when □~□ of the thigh region were compared, the hardness for the overall region could be seen to be higher for the left side, and is the pattern observed for the third largest number of personnel of 6 people.

4. Conclusion

In the present study, static load tests and body pressure distribution tests were conducted to derive the seat cushion pattern models having a multi-hardness distribution for automobiles. According to the results of analysis by combination of two tests, the following conclusions could be obtained.

- Through static load tests of the seat cushion, the characteristics of deflection in the seat cushion as a function of loads were identified, and shown by the graph. Also, hardness values and functional equation at each point were derived.
- In the deflection graph for the seat cushion as a function of loads, the phenomenon could be affirmed where the slopes of P52 and P67 as the end part of the bolster showed a steep increase. This phenomenon was attributed to the occurrence of thickness differences in each region of the seat cushion. Based on this observation, thicknesses of the seat cushion were also shown to be a factor which could affect hardness values.
- By application of the functional equation derived from static load tests to the data of body pressure distribution, a total of 11 seat cushion pattern models having 8-hardness distributions were derived. Through the analysis combining two types of test results including static load tests and body pressure distribution tests.

5. Acknowledgement

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