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Study on Performance Evaluation of Mechanical and Pneumatic Lumbar Support for Passenger Cars

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Abstract

In the present study, Lumbar Support, according to 2 types of methods was mounted on the driver's seat of a passenger car for a comparative analysis of performance. For experiments, the amounts of swelling upon operation and of the deflection as a function of changes in the load were obtained with emphasis on a static load compression test, an elasticity restoration test, and the H/point. Also, actual pressure distributions produced between the human body and the seat were measured and analyzed. Following this, the performance difference for the two types of lumbar support was analyzed and the ergonomic effects of the characteristics were discussed.

Keywords: *passenger car, Lumbar Support, Body pressure distribution, Car seat*

1. Introduction

Automotive seats should be designed by comprehensive consideration of stability, comfort, convenience, design, *etc* [1-2]. Consequently, ergonomics and emotional engineering are being deeply reflected, unlike general seats. The parts affecting fatigue and comfort felt during automobile driving are the neck, shoulder, lumbar, hip, etc., and posture or feeling of the lumbar part of the waist among which has the greatest effects [3-4]. Lumbar support, as one of the seat parts, is an auxiliary apparatus relieving a tired feeling during driving for a long time by supporting pressures applied to the waist. The lumbar support prevents falling backward by supporting the pelvis, and plays a role of supporting vertebra on the waist side and the upper body. About 75% of body weight is supported by the hips, and about 25% of the body weight, in particular, is concentrated on the ischial tuberosity part of the body [5-6]. Considering body pressure distribution, the distribution is varied with the angles of seat and backrest, and overall pressure values should be maintained at a low level by sufficiently enlarging the contact face. Driving for a long time hinders blood circulation of the lower body, causing the feet to be swollen. As an evaluation method concerning the comfort of the chair felt by the driver, body pressure distribution between the body and the seat face is often used. The measurement technique for body pressure distribution uses data on the distribution of the driver's body pressure, measured through a pressure matrix installed in the driver seat to conduct an analysis. Since the vertebra height and pelvis size vary from person to person, adjustment according to each passenger's form is important. Whereas it is distributed flatly, with loads distributed on the lumbar part when seated on a seat with the lumbar support mounted, it may be seen to be pressed by concentrated loads otherwise. Used for its lumbar support, recently applied to automotive seats, is the lumbar support of a 4-way control method by a motor control as shown in Figure 1(a), and lumbar support of an pneumatic control method which causes swelling by compressing air using a compressor and putting the air in an pneumatic blade [7]. In the present study, lumbar support,

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according to 2 types of methods was mounted on the driver's seat of a passenger car for a comparative analysis of performance. For experiments, the amounts of swelling upon operation and of the deflection as a function of changes in the load were obtained with emphasis on a static load compression test, an elasticity restoration test, and the H/point. Also, actual pressure distributions produced between the human body and the seat were measured and analyzed. Following this, the performance difference for the two types of lumbar support was analyzed and the ergonomic effects of the characteristics were discussed.

(a) Mechanical Lumbar Support (b) Pneumatic Lumbar Support

Figure 1. Types of Lumbar Support

2. Experimental Equipment and Experimental Conditions

The model employed in the present experiments was tested for the object of lumbar support of the kinematic 4-way control by a motor and pneumatic-type lumbar support composed of 3 stage-type braids as shown in Figure 1(b). This model is a model mounted on commercial passenger car seats, and subjected to experiments by being mounted onto the driver seat. First, the structure of the kinematic 4-way power lumbar support is as shown in Figure 1(a). It has a structure composed of a motor for up and down movement, a motor for left and right movement, a bumper plate directly supporting the waist for the seat, etc. where amounts of the protrusion of the seat are made to be controlled by the two motors.

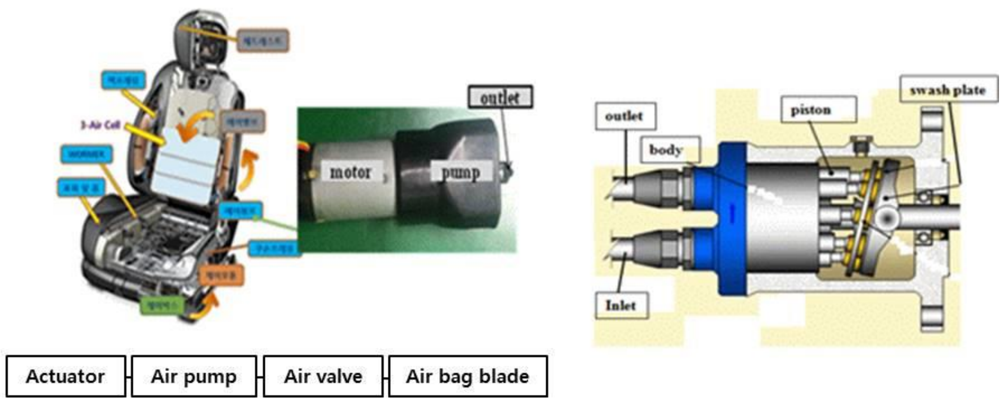


Figure 2. The Block Diagram for Pneumatic Lumbar Support

Next, the block diagram for pneumatic lumbar support of Figure 1 is as follows. First, air is produced through a rotary actuator and pump for driving, and supplied to a multi-stage air bag blade through a valve for direction of the air and opening/closing to be driven by a control apparatus. In general, a swash plate-type pneumatic compressor with good quantitative control and low vibration is employed for the pump applied to the automobile lumbar support, whose external structure is as shown in Figure 2.

First, the equipment used for the static load tests is a piece of equipment dedicated to seat testing as shown in Figure 3. Equipment configuration contains the mounting of a load cell to measure the load variables and a LVDT sensor to measure deflections from the seat at that time, and consists of a control device to store data measured in real time, *etc*. Then, the 3-dimensional scanner which enables simultaneous measurements in 3-axis directions was used to measure positions per each spot as shown in Figure 4. Here, to apply the same weight as the person actually sitting on the seat, a human body dummy was used. The weight of the dummy was 75 kgf, about 75% of which was installed to allow the application to the cushion seat part and about 25% to the back seat part with the lumbar support mounted as shown in Figure 5. Experimental data was analyzed after real-time storage through an A/D board. Also, to make switch operation times and intensities constant, a robot was employed to operate according to a control program for improvement of reliability.

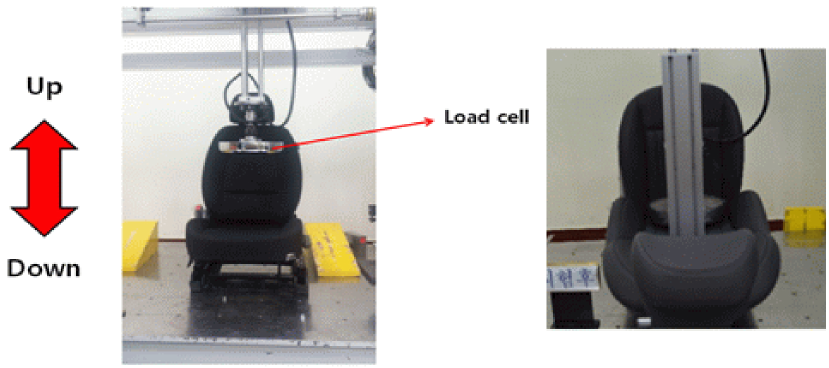


Figure 3. Static Load Test

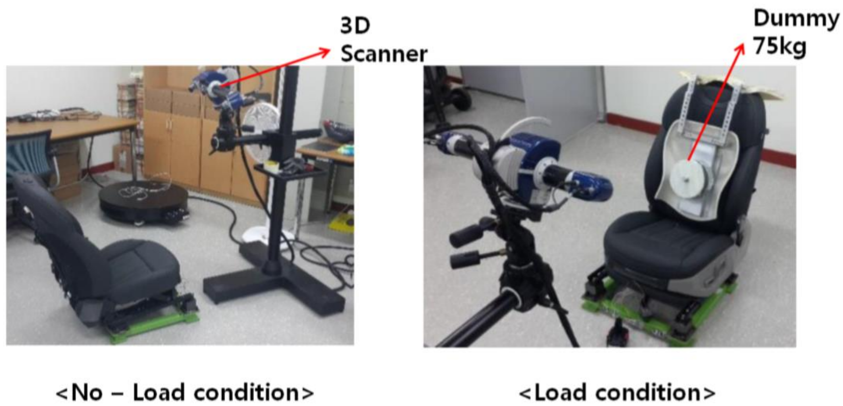


Figure 4. The Projection Test by 3-D Scanner

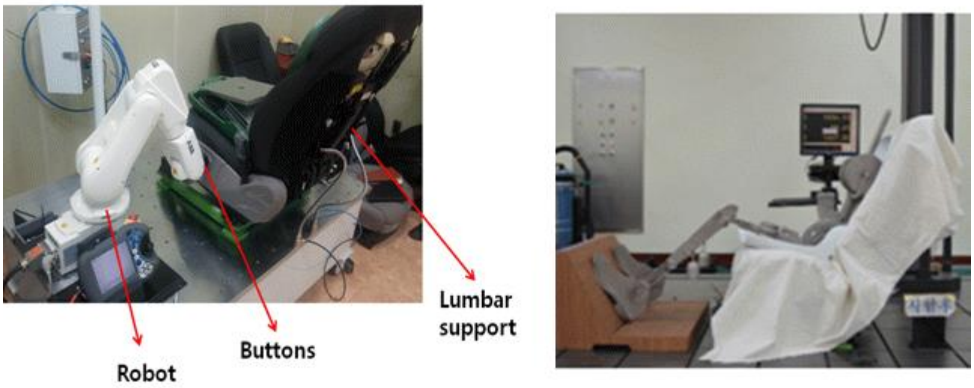


Figure 5. Dummy Load Test by Robot

Lastly, to analyze the distribution of the loads acting on the seat surface, a measurement distribution diagram was checked by using a mat-type body pressure distributor. The equipment employed was a product from model SENSOR X3 Pro of the Xsensor Company with the installation of 2,304 sensors [8]. The body pressure distributor employed was installed on the whole area of the seat as shown in Figure 6, and the distribution diagram for body pressures acting at that time was schematized.

Figure 6. Body Pressure Distribution Test

3. Experimental Results

First, compressive strengths and elastic forces were measured while loads on the seat surface were increased, and the following results were obtained. Figure 7 shows the measured results of deflection as a function of change in loads obtained through the static load tests. Here, in the case of mounting the mechanical type of lumbar support, the amounts of protrusion were 15.7 mm upon application of 15kgf of load, and 30.1mm under 30kgf. The maximum amount of protrusion was shown to be between 43mm and 43.6mm. Maximum deviation occurred at an application of 30kgf of load and upon the removal of the load was measured to be about 8mm. Next, in the case of mounting the pneumatic-type lumbar support, the amount of protrusion was measured to be 15.2 mm upon the application of 15kgf, which became 27.9 mm when the load was increased to 30kgf, with the maximum amount of protrusion shown to be between 43mm and 40.5 mm. The deviation between the time for application of 30kgf of load and the time for removal of the load was observed to be similar to that for the mechanical type.

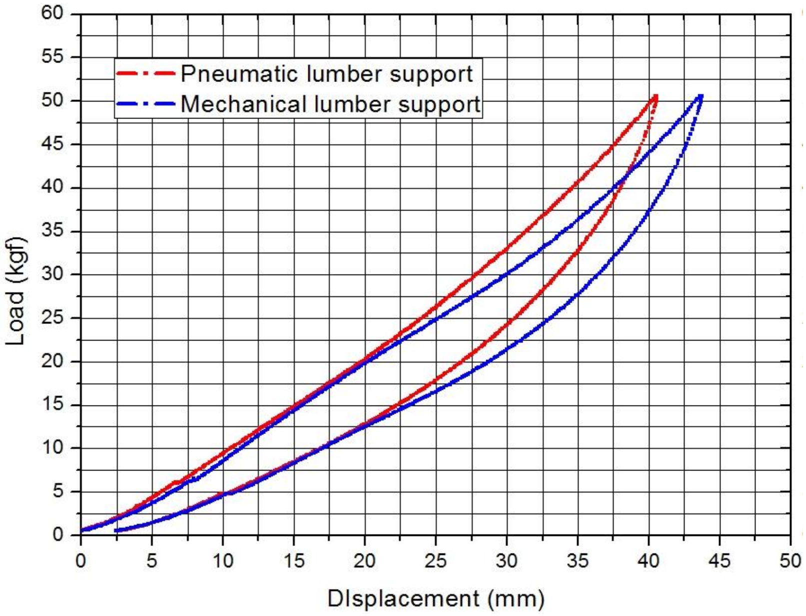
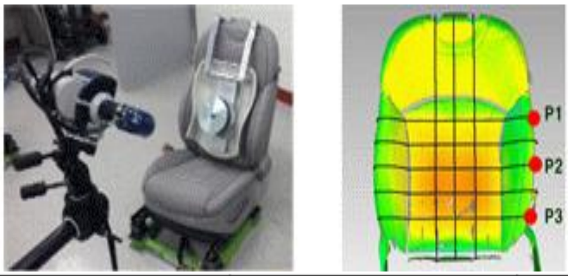


Figure 7. Result of Static Load Test

This was followed by the measurement of the maximum amounts of protrusion for the lumbar support per seat height according to the 3D scanner. For the installation condition, the angle of inclination for the back seat was 23° and 3 points were measured for the heights at the lowermost (p1) part, the intermediate (p2) part, and the uppermost (p3) part, respectively, to obtain the amounts of protrusion. As a result, what were 24mm at p1 part, 33mm at p2 part, and 23mm at p3 part upon no load as shown in Figure 8 were changed to 6mm, 13mm, and 17mm for p1, p2, and p3, respectively upon the application of a dummy load of 30kgf as shown in Figure 4(a), showing a considerable reduction. Lastly, body pressure distributions according to each condition were measured for observation and analysis concerning the actual effects on the waist. Through this analysis, it was affirmed that pressures were uniformly distributed between the human body and the seat upon mounting the lumbar support to disperse concentrated loads, due to which comfort could be seen upon driving. A difference in the amounts of protrusion between the pneumatic type and the mechanical type is schematically. Here, whereas the pneumatic type showed a large protrusion in the Forefront part and the Upper part of the seat upon no load at 2.1mm and 1.5mm, respectively, as shown in Figure 8, the mechanical type showed a large protrusion at 3.9mm in the Lower part. In the case of loads, 3 parts showed a similar tendency. This is considered attributable to the fact that the operating space became wider in the case of the pneumatic type by installation of a motor and compressor at separate locations and connection with a hose, although protrusions were severe upon no load in the case of the mechanical type as the mat and machine mechanism were basically installed on the rear face of the seat plate.

Next, Figure 9 shows the result for the distribution diagram by measuring body pressures per part for 2 types of models. When considered in the standard mode, the pneumatic type shows a uniform pressure distribution as a whole. Also, stresses can be seen to be dispersed to the center in the case of the pneumatic type, although stresses in full down mode were concentrated in the shoulder part in the case of the mechanical type.

To check for the difference in the body pressure distribution diagram between the mechanical type and the pneumatic type lumbar supports as shown in Figure 10, it is schematically shown in Figure 11 together with SBD(Support Balance Diagram) applied to commercial vehicles [9]. As shown in this Figure, the curve for the pneumatic lumbar support was affirmed to approach the optimal line in comparison with that for the mechanical type. From this observation, the pneumatic type can be seen to be ergonomically excellent upon driving with application to the actual seats.



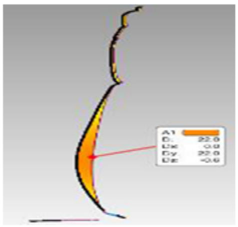
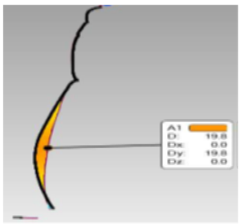
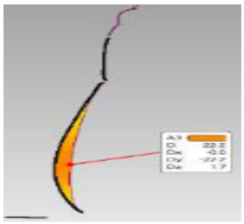
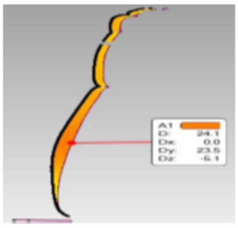
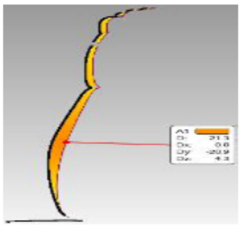
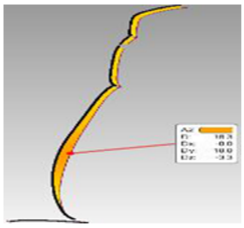
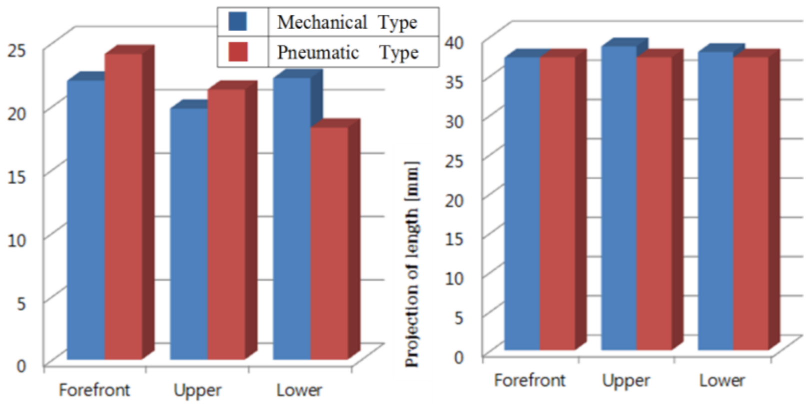
Type / Position	Forefront	Full up	Full down
Mechanical type			
Length	**22.0mm**	**19.8mm**	**22.2mm**
Pneumatic type			
Length	**24.1mm**	**21.3mm**	**18.3mm**
Gap	**2.1mm**	**1.5mm**	**3.9mm**

Figure 8. Result of the Projection Test by 3-D Scanner



(A) No Weight Load (B) Weight Load Applied

Figure 9. Projection Length of Lumbar Support

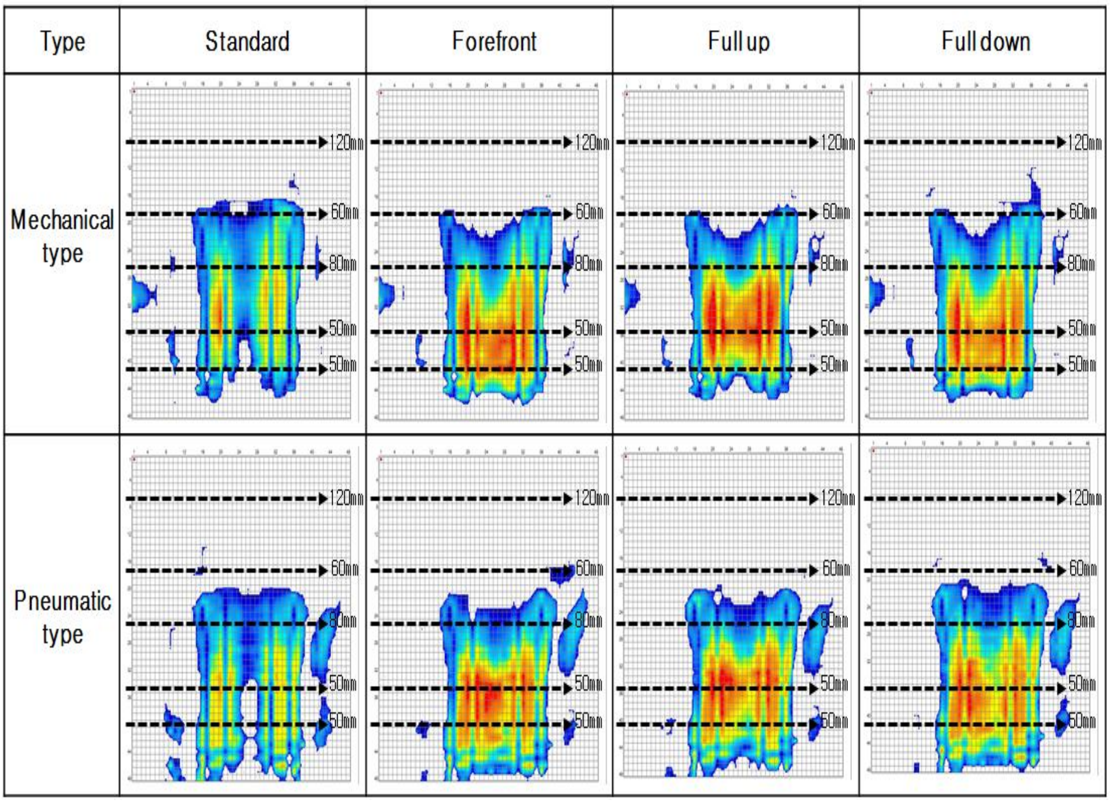


Figure 10. Body Pressure Distribution Test

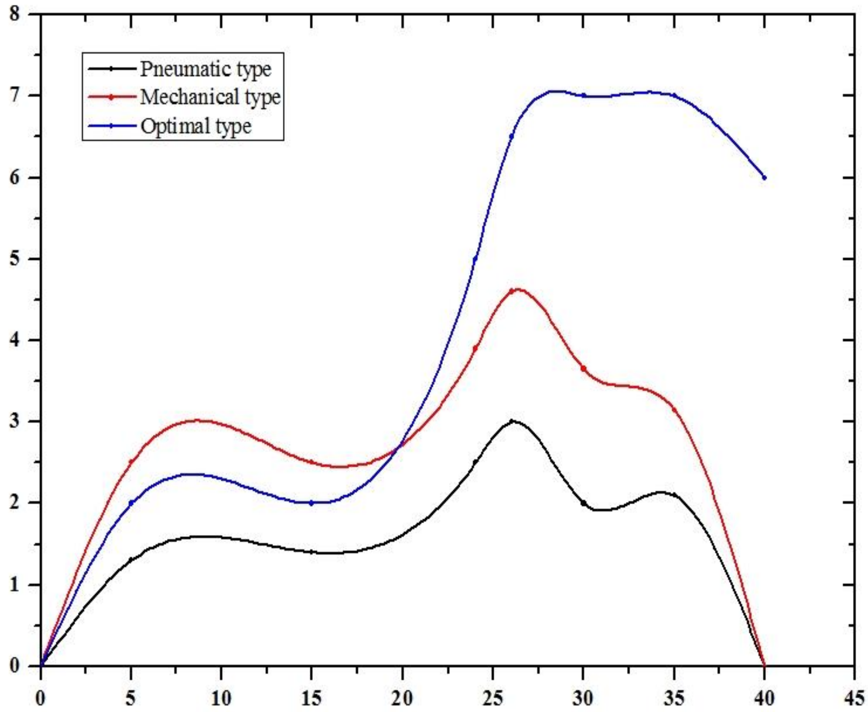


Figure 11. Support Balance Diagram for Lumbar Support

4. Conclusions

In the present study, static load characteristics, deflections as a function of change in loads, and actual pressure distribution produced between the human body and the seat were measured and analyzed to comparatively analyze the performance of a kinematic 4-way Power Lumbar Support according to a motor control and an pneumatic type lumbar support recently applied to luxury passenger car seats. The following conclusions were obtained.

1. According to the measured results of compressive strengths and elastic forces with an increase in loads on the seat surface, the amount of protrusion under 30kgf was measured to be 30.1mm in the case of mounting the mechanical type lumbar support, and the maximum deviation between the application and the removal of the load to be about 8mm. In the case of the pneumatic type, the deviation was measured to be similar to that of the mechanical type.

2. Based on the measured results for the maximum amounts of protrusion per seat height according to a 3D scanner, what were 24mm for p1 part, 33mm for p2 part, and 23mm for p3 part upon no load became 6mm, 13mm, and 17mm, respectively, upon the application of a 30kgf dummy load, thus showing a considerable reduction.

3. According to the analysis results for the distribution diagram by measuring body pressures per part for 2 types of models, whereas the pneumatic type is shoeing a uniform pressure distribution as a whole. While stresses were concentrated in both shoulder parts for the mechanical type, stresses can be seen to have been dispersed toward the center for the pneumatic type. In the SBD analysis, the curve for pneumatic lumbar support was also affirmed to approach the optimal line in comparison with that of the mechanical type. Based on this observation, the pneumatic type can be seen to be ergonomically excellent upon driving with application to actual seats.

Acknowledgments

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