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Characterization of Rubber Sack for Seating Evaluation System†

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A flexible and stretchable rubber sack is used as a seating evaluation system to measure the figures and postures of people. A rubber sack filled with plastic pellets are prepared by folding and adhesion with a thin rubber sheet. For better design architectures, the rubber sheet requires a lower modulus and higher elongation because of the easy stretch and stretch and flexible deformability. In addition, the adhesion strength is an important quality factor of a rubber sack to guarantee the reliability of the system. Furthermore, the resistance of movement of the pellets should be reduced to obtain good deformability. This study found that the adhesive strength of an overlapped type rubber sack was more than 10 times higher than that of a butted type rubber sack. The flexibility and deformability of rubber sacks with oily pellets was more than double those with non-oily pellets. Overall, the performance and reliability for a seating evaluation system can be improved using a rubber sack filled with oily pellets.

Key Words: Seating evaluation system, Rubber sack, Material property, Deformability, Oily pellets, Adhesive strength.

INTRODUCTION

Customized seats are required for the comfort and functionality of the general public and handicapped. A custom-molded seat and the back shape of a wheelchair or scooter for rehabilitation were created to provide the necessary support, maximize the pressure distribution and increasing comport[1-4]. A simulation of the occupied seat has strategic relevance for all vehicle manufacturers[5].

A seating evaluation system was used to measure the individual figure and posture of each person for custom seating. A flexible and stretchable rubber sack filled with plastic pellets is used in seating evaluation systems. The shape of the rubber sack can be molded to the human body shape and posture. When the air in the sack is extracted and the sack is sealed, the rubber sack becomes solidified and maintains its shape because there is no space between the plastic pellets. The shape of the solidified rubber sack is generally measured using a 3-D scanner to fabricate a customized seat. Fig. 1 shows the process to manufacture the customized seat. Fig. 1 (a) presents the seating evaluation system with a rubber sack and Fig. 1(b) presents the adjustment according to the figure and posture of a person. Fig. 1(c) presents the 3-D scanning process and Fig. 1(d) provides a digital mock-up of the customized seat. Fig. 1(e) shows a sample of the customized seat.

A rubber sack filled with plastic pellets was made by folding and adhesion with a thin rubber sheet. An air nozzle was present in the side of the rubber sack to inflate and evacuate the air in the rubber sack. Fig. 2 shows the rubber sack: (a) inflated and (b) evacuated.

To produce the rubber sacks, the material properties of the rubber sheet need to have a lower modulus and higher elongation for easy stretching and deformability. This study investigated several types of rubber including natural rubber and silicone rubber and selected the appropriate rubber materials for a rubber sack.

The adhesive strength is an important parameter for the quality of a rubber sack to guarantee the reliability of the system. Double coated adhesive tape is generally used for adhesion. The rubber sack was prepared using two methods. The traditional method was a butt type adhesion and the new method was an overlapped type adhesion[6]. The rupture strengths of each prototype sample were compared.

The resistance of movement and the deformation of pellets must be reduced to improve the performance and accuracy of the seating evaluation system. The low friction and smoothness between pellets, as well as between the pellets and rubber sack are needed to guarantee the smooth movement of pellets and deformation of the rubber sack. In this study, oily pellets were used to enhance the movement and

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deformability and evaluate the deformability using the load-deflection test.

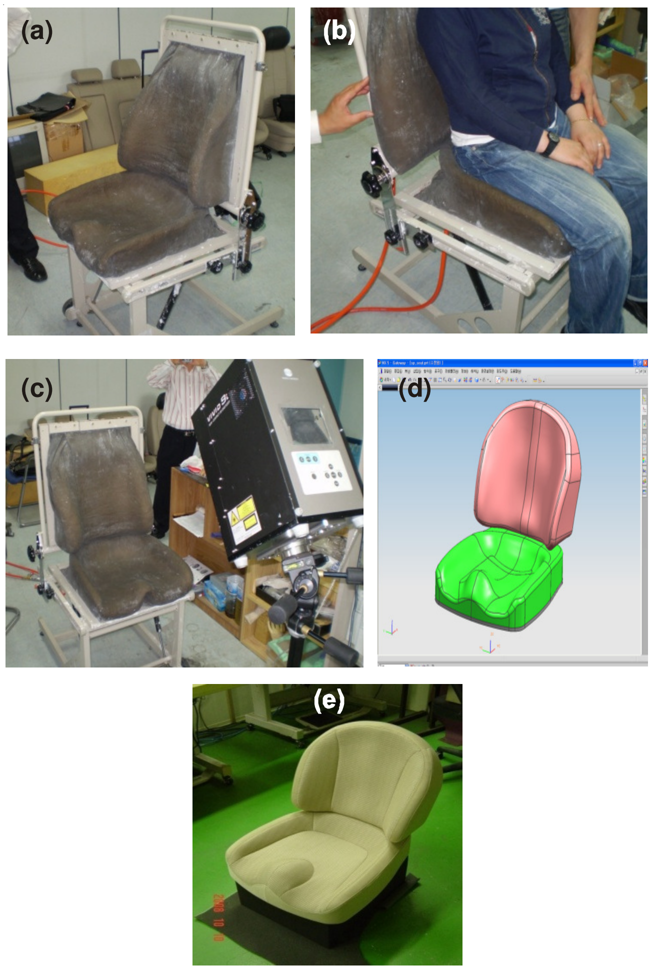

Fig. 1. Manufacturing process of a customized seat, (a) seating evaluation system with a rubber sack, (b) adjustment of the shape, (c) 3D scanning process, (d) digital mock-up of the customized seat and (e) sample of the customized seat

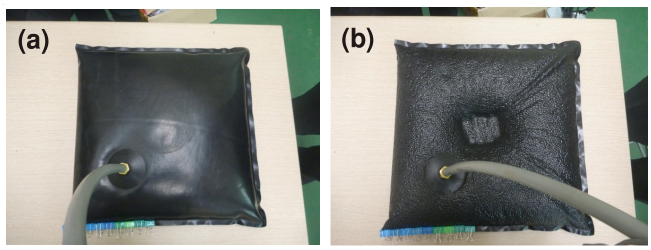

Fig. 2. Sample of the Rubber sacks: (a) inflated and (b) evacuated

EXPERIMENTAL

Test of rubber sheet: Several types of rubber sheet materials were investigated. The hardness of NR 1 and NR 2 was IRHD 50 and 70, respectively. The material of Q1~Q3 was the same as that for silicon rubber but the thicknesses of the sheets were different. A rubber specimen, 50 mm in length, with a dumbbell shape was prepared and the tension test was performed according to the modified ADTM D412. Table-1 lists the chemical compositions of natural rubber NR1 and NR 2. Fig. 3 shows the tensile testing equipment of the rubber sheet.

TABLE-1
COMPOUND COMPOSITIONS OF NATURAL RUBBER

	NR 1 (phr)	NR 2 (phr)
Natural rubber	100	100
Sulfur	2.5	2.0
Zinc oxide	7.0	7.0
Stearic acid	5.0	5.0
Carbon black	25.0	72.0
Oil	3.0	6.0
Accelerator	1.0	1.2

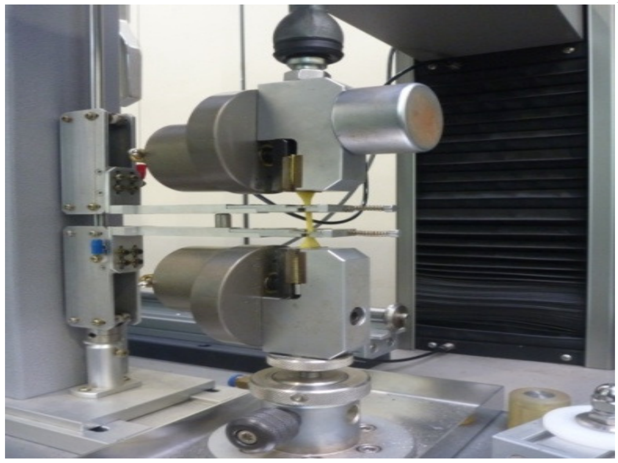

Fig. 3. Tensile test equipment of the rubber sheets

Adhesive strength test: Two adhesive methods can be used to make a rubber sack using a thin rubber sheet. One is the traditional method, which is a butt type method and the other is a new overlapped type method. Double coated adhesive tape (3 M, 9080 HL) was used. Table-2 lists the properties. Two specimen types were prepared to measure the adhesive strength, as shown in Fig. 4. Fig. 5 shows the test set-up of each type specimen.

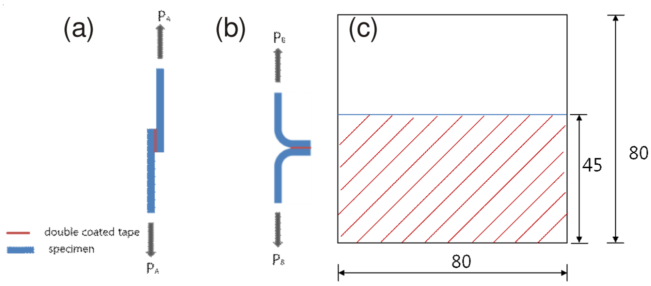

Fig. 4. Adhesive Methods, (a) butt type, (b) overlapped type and (c) dimension of the specimen

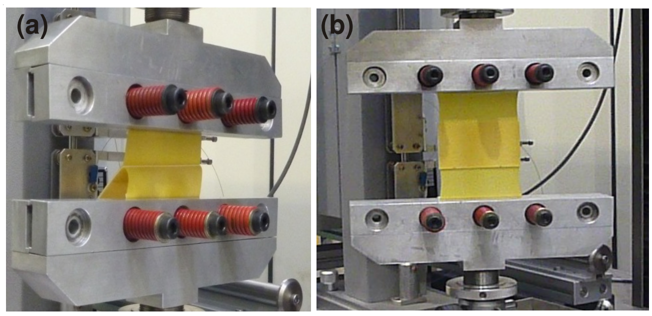

Fig. 5. Test set-up for the adhesive strength, (a) butt type and (b) overlapped type

TABLE-2
PROPERTIES OF THE ADHESIVE TAPE

Product name	Adhesion type	Thickness	Peel strength (ASTM-D3330)	Dynamic shear strength (ASTM-(D1002)
3 M 9080 HL	Tackified acrylic adhesion	0.16 mm	0.75 N/mm	31.9 N/cm^2

Rupture strength test: The general failure mode of a rubber sack filled with plastic pellets for seating evaluation systems is the rupture of the adhesive area. The rubber sack can rupture if there is any crack or breakage in the adhesive area of the sack. The rupture strength of the two type rubber sacks were compared using scale-down rubber sacks. Fig. 6 presents drawings of scale-down rubber sacks and Fig. 7 shows the test set-up for the rupture strength.

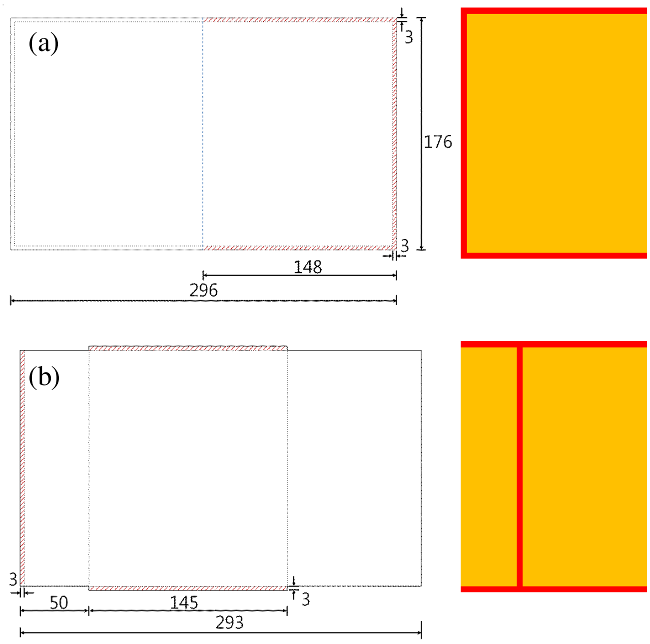

Fig. 6. Drawings of the scaled-down rubber sack, (a) butt type and (b) overlapped type (the thick solid line is the adhesive area)

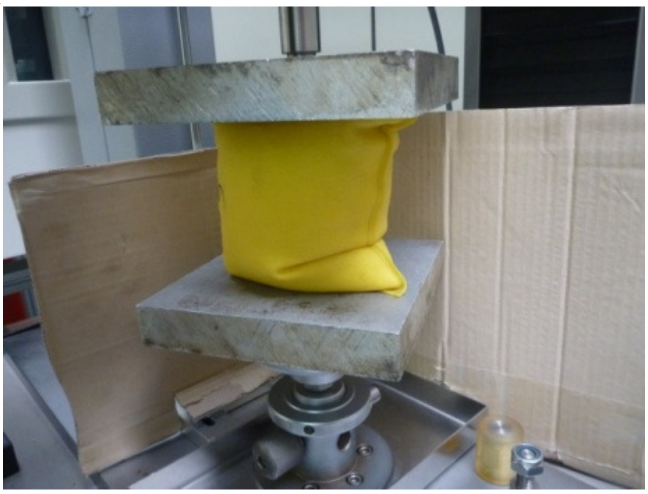

Fig. 7. Test set-up for the rupture strength

Deformability test: Table-3 lists the properties of the polyethylene pellets. The pellets were round and 3-5 mm in size, as shown in Fig. 8. Rubber balloons filled with pellets were used to compare the deformability of the rubber sack with oily pellets and non-oily pellets. Six balloons filled with 70 g weight of oily pellets and non-oily pellets were prepared to minimize the experimental error. Fig. 9 presents the test set-up.

TABLE-3
MATERIAL PROPERTIES OF THE PLASTIC PELLETS

Material	Density (g/cc)	Compressive modulus (GPa)	Coefficient of Friction	Shape and size
HDPE (High Density Polyethylene)	0.927-1.45	0.29-0.689	0.02-0.35	Round 3~5 mm

Fig. 8. Polyethylene pellets

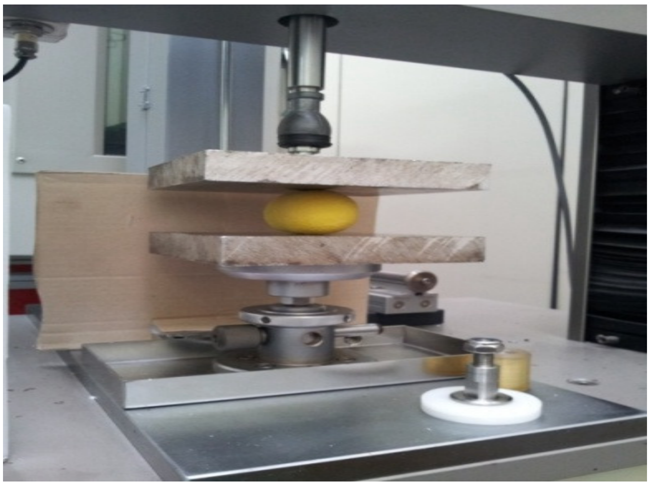

Fig. 9. Test set-up for deformability

RESULTS AND DISCUSSION

A tensile and compression tester (Daekyung engineering©, DUT-500C) with a load cell of 500 kg and 1 ton was used.

Material properties of rubber sack: Figs. 10-14 show the stress-strain curves of the tensile tests. Three samples were tested for each type rubber sheet. Table-4 lists the material properties of the rubber sheets.

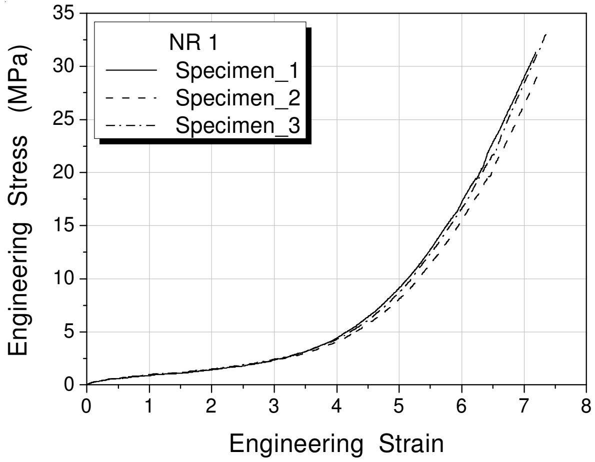

Fig. 10. Stress-strain curves of NR 1

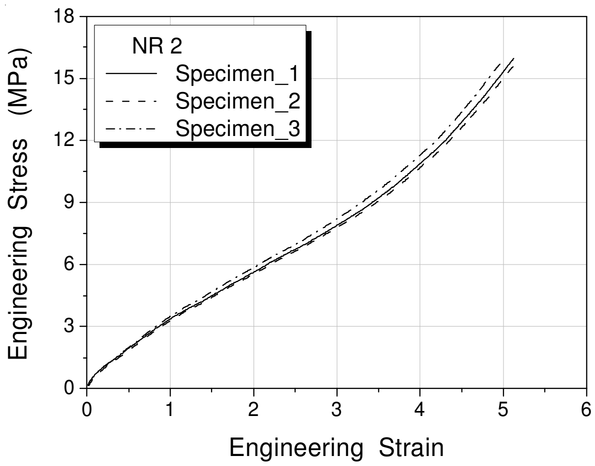

Fig. 11. Stress-strain curves of NR 2

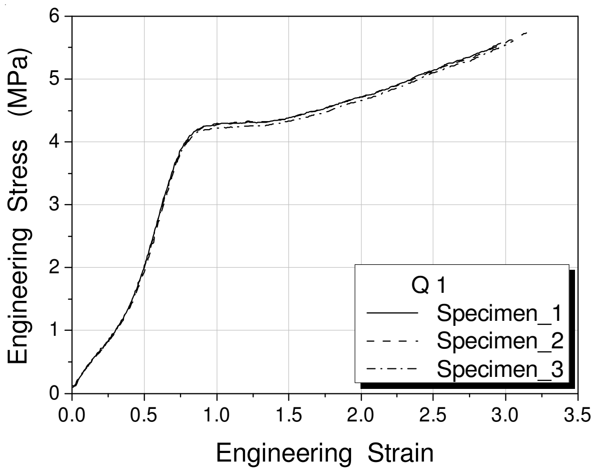

Fig. 12. Stress-strain curves of Q1

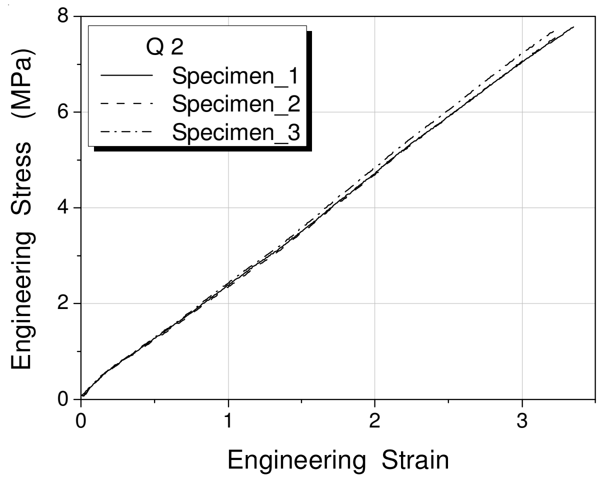

Fig. 13. Stress-strain curves of Q2

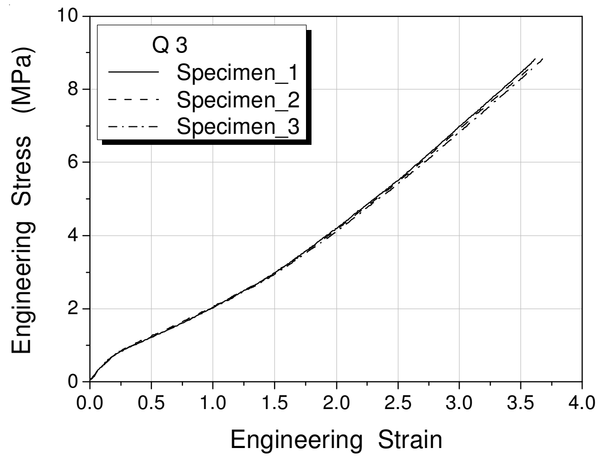

Fig. 14. Stress-strain curves of Q3

TABLE-4
MECHANICAL PROPERTIES OF THE RUBBER SHEETS

Type	Material of rubber sheet	Hardness (IRHD)	Thickness (mm)	Tensile strength (MPa)	Elongation (%)
NR 1	Natural Rubber	50	0.53	26.7	739
NR 2	Natural Rubber	70	0.45	15.8	507
Q 1	Silicon Rubber	64.5	0.45	5.6	305
Q 2	Silicon Rubber	65.0	0.82	7.7	326
Q 3	Silicon Rubber	66.5	1.13	8.7	362

The test results showed that NR 1 was better than the others because of the lower modulus and higher elongation. In addition, NR 1 provided a good linear relationship between the stress and strain under approximately 400 % strain. NR 1 could be stretched and deformed easily.

Adhesive strength: Fig. 15 shows the test result of the adhesive strength of the two types. The adhesive strength of the overlapped type and butt type was approximately 47 N and 16 N, respectively, showing approximately 3 fold improvement in adhesive strength.

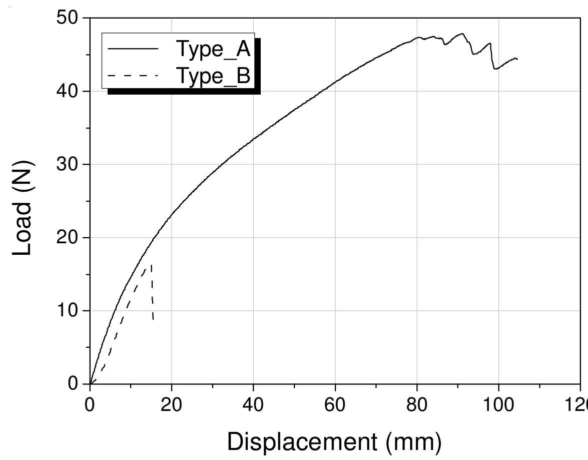

Fig. 15. Adhesion strength curves

Rupture strength of sack: Fig. 16 shows the experimental results of the rupture strength test of three specimens for each case. The rupture strengths of each specimen showed some scatter. Fig. 17 compares the maximum rupture strength of the overlapped type and butt type. The rupture strength of the overlapped type was in excess of 3000 N, which is 12 times higher than that of the butt type (250 N). This distinction was caused by the difference in the region of adhesion. The adhesion of the butt type occurs on the line of the attached surface and the adhesion of the overlapped type occurs in the area of attached surface. Finally, the rupture strength was enhanced significantly using the overlapped adhesive method.

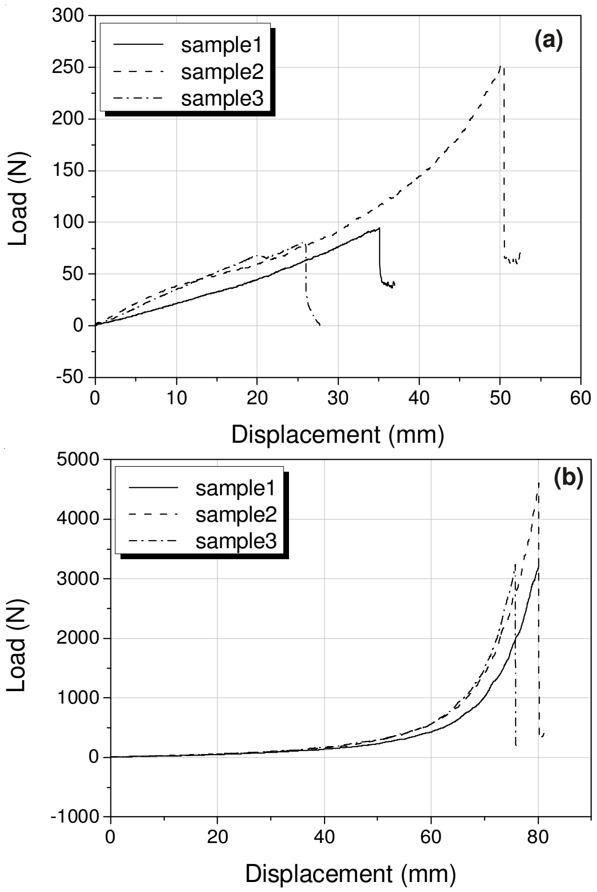

Fig. 16. Rupture test of a scale-down sack, (a) butt type and (b) overlapped type

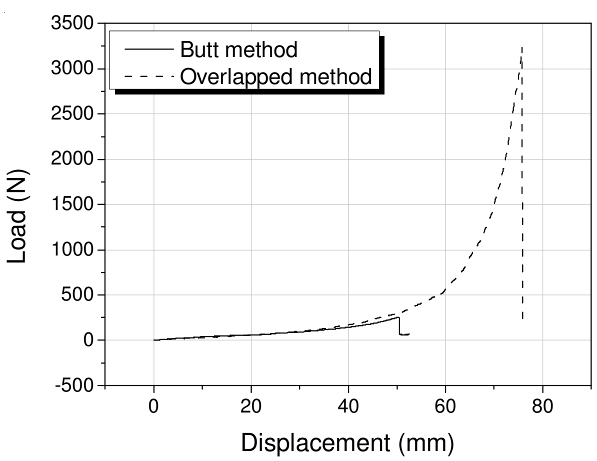

Fig. 17. Comparison of the maximum rupture strength

Effect of oily pellets on deformability: The compressive test was performed to ensure the difference between the two types of balloons with oily plastic pellets and non-oily plastic pellets. As shown in the p-δ graph in Fig. 18, the stiffness of the balloons with oily pellets was lower than that of the non-oily pellets. The average stiffness in the case of the oily pellets was approximately half that of the non-oily pellets. Furthermore, the p-δ curves of the oily pellets showed more uniform characteristics than those of the non-oily pellets. This might be caused by the lower friction between the oily pellets and between the rubber and pellets.

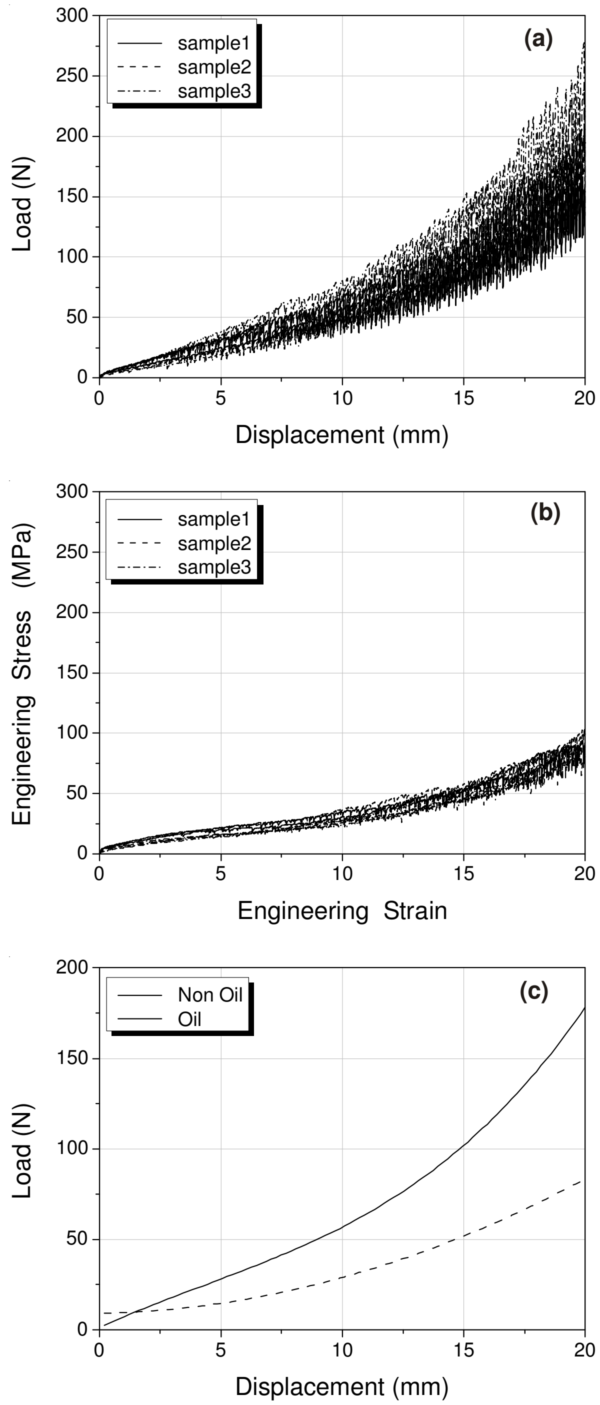

Fig. 18. Effects of the oily and non-oily pellets on the load-displacement curves, (a) with non-oily pellets, (b) with oily pellets and (c) average load-displacement curves

Conclusion

The characteristics of rubber sacks for seating evaluation systems were examined using material tests, adhesive strength tests, rupture tests and deformability tests.

The material properties of the rubber sheet with a lower modulus and higher elongation were selected. This rubber sheet provided easy stretching and flexible deformability.

The adhesive strength of the overlapped type was more than 3 times that of the butted type and the rupture strength of the overlapped type was 12 times higher than that of the butted type. Furthermore, the flexibility and deformability of the rubbersacks with oily beads were two times higher than those with non-oily beads. Overall, the performance and reliability of rubber sacks for seating evaluation systems was improved using a lubricant and overlapped adhesive rubber.

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