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DESIGN OF AIR SEAT CUSHION ORTHOSIS FOR PLEGIA

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ABSTRACT

The design of an air seat cushion for preventing decubitus ulcer includes many design factors such as the even distribution of interface pressure, the minimization of mean and peak interface pressure values, and the reduction of interface shear force and pressure gradient. It involves the anatomic condition of plegia's buttock as well as air pressure in air cells of cushion. As a result, a suitable design of the cushion satisfying the all requirements is a difficult problem. Therefore, an appropriate and effective numerical tool to develop an air cushion orthosis is required. The purpose of the present study was to develop an air seat cushion orthosis having optimized air cells for evenly distributed interface pressure between the buttock and cushion surface. For the purpose, an advanced finite element (FE) model for the design of air cushion was developed. Since the interface pressure and shear force behavior, as well as stress analyses were primary concern, a FE air cell model was developed and verified by the experiments. Then, the interactions of two cells were checked. Also, the human part of the developed numerical model includes every material property and geometry related to buttock and femoral parts. For construction of dimension data of buttock and femoral parts, CT scans were performed. A commercial FE program was employed for the simulation representing the seating process on the orthosis. Then, sensitive analyses were performed with varying design parameters. A set of optimal design parameters was found satisfying the design criteria of the orthosis. The results were utilized to produce a prototype of the orthosis. Experimentally, the buttock interface pressure distributions from the optimized and previous ones were compared. The new seat orthosis showed a significantly improved interface pressure characteristics compared to the most popular one in the market. The new orthosis will be used for the development of the AI (artificial intelligent) controlled seat orthosis for prevention of decubitus ulcer for various plegic patients and the elderly.

Key Words : Seat Cushion Design, Decubitus Ulcer, Rehabilitation Engineering, Explicit Finite Element Air Cell Model

1. INTRODUCTION

The use of seat cushion orthosis is required for various plegic patients and the elderly to prevent pressure sore. To design of an air seat cushion for prevention of decubitus ulcer, interface pressure characteristics between the buttock and cushion are important. The main design factors could be the distribution of interface pressure, the minimization of mean and peak interface pressure values, and the reduction of interface shear force and pressure gradient. Thus, a suitable design of the cushion satisfying all requirements is a difficult problem. To develop an air seat cushion orthosis, an appropriate and effective numerical tool is required. In addition, it is required that the shape of a seat orthosis would be alternating based on the anatomical position of buttock. The alternation of shape should be intelligently controlled to adapt for a buttock of arbitrary user. To apply AI (artificial intelligent) control to seat orthoses, the air could be the best as a controlling medium.

The purpose of the study was to develop an air seat cushion orthosis having optimized air cells representing evenly distributed and lower interface pressure between the buttock and cushion surface. For the purpose, advanced finite elements (FE) of cushion and human buttock models were utilized.

2. METHODS

Since the interface pressure, as well as deformation behavior of air cell in the cushion were concerns, an air cell was modeled using the airbag model in PAM-SAFE (ESI, France). Figure 1 was the base FE model of air cell. The material of air cell was the chloroprene rubber that is mostly used in the air cushion orthosis. Since the inflating behavior of air cell in the service range, the material behavior is assumed to be linear. The material properties were obtained from experiments using the chloroprene rubber specimens. The inflating behavior of air cell model was checked by experiments. The completed base FE seat cushion model showed in Figure 2.

The human buttock model was constructed using dimensional data from CT scanning of a plegic patient. The material properties of hard and soft tissues were obtained from previously developed the H-model (IPS International, Korea).

The analysis is composed of two procedures. Firstly, the inflating simulation of the seat cushion up to the service air cell pressure was performed. Then, the human model was seated on the orthosis model to obtain the interface pressure characteristics. Figure 3 was the simulation configuration using the orthosis and human model.

To obtain appropriate, or near optimum design of the orthosis, a design procedure was applied using a sensitivity analysis. The design factors were the height of air cell, the number of rib of air cell on the transverse plane, and the density of air cell in the orthosis. For all cases, the sensitivity analyses were performed to obtain a near optimal design of the orthosis.

3. RESULTS AND DISCUSSION

Figure 4 shows the comparisons of air cell behavior form the experiment and simulation. The expansion curves of air cell shows a reasonable agreement. Figure 5 shows the interface pressure distributions from the test (left) and simulation (right). For the sensitivity analyses, an optimum height of air cell minimizing interface shear force and maximum pressure was 60 mm (Figure 6 and Table 1). An optimum number of rib of the air cell was 8 based on the strain distribution (Figure 7). The density of air cell was selected as a medium density. After optimizing, the interface pressure characteristics were significantly improved compared to those of the base orthosis model (Figure 8). Figure 9 shows the completed seat orthosis system that will be produced in near future. The alternation of orthosis surface shape will be done by the air and controlled by the Fuzzy Controller.

Fig. 1

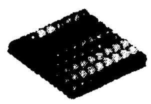

Fig. 2

Fig. 3

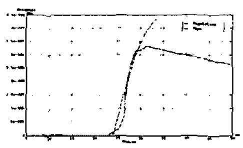

Fig. 4

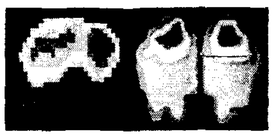

Fig. 5

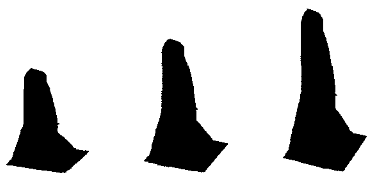

Fig. 6

Table 1.

Cell	40mm	60mm	80mm
Shear	12.3 N	9.5 N	32.0 N
Max.	15.6kPa	12 kPa	13.2kPa

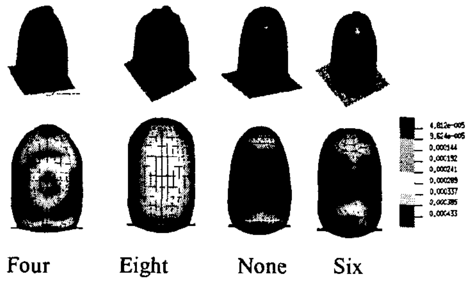

Fig. 7

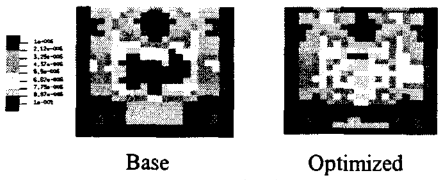

Fig. 8

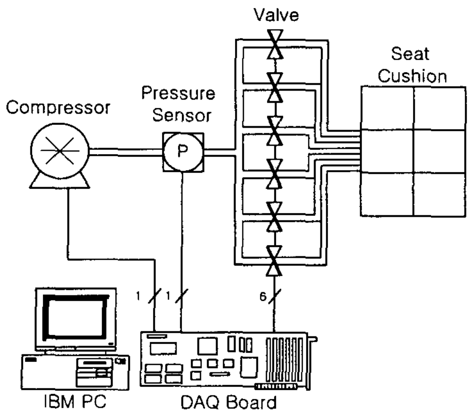

Fig. 9

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