Computational Simulation on Facial Expressions Using Finite Element Analysis

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Abstract. The purposes of this research are to identify mechanical properties of silicone rubber used as artificial skin and perform computational simulation on facial expressions using Finite Element Analysis (FEA). The tensile test was carried out to find mechanical properties of silicone rubber. Calculations on facial expressions were carried out using the mechanical properties of artificial skin of silicone rubber identified by the tensile test.

Keywords: facial expression, artificial skin, silicone rubber, tensile test, FEA.

1. Introduction
In recent years, the applications of robotics become important for human life in the worldwide. The robot on facial expressions has developed by following human facial expressions [1]. It is required to examine the positions and directions of forces loaded on a robot face in order to make the robot express the same facial expressions as human’s ones [2]. The directions and the magnitudes of forces depend on the shapes of robot facial expressions [3].

Firstly, the tensile test was carried out on silicone rubber (RTV2 VP 7550) used as artificial skin of robot face. Secondly, the mechanical properties of artificial skin were identified using the experimental and FEA’s results. Thirdly, the facial shape was measured by 3D scanning. In addition, the facial model was made by meshing the 3D scanning data. Finally, the calculated results of facial expressions using FEA were compared with real human facial expressions.

2. Experimental on mechanical properties of artificial skin
2.1. Experimental Setup
The schematic representations of tensile test set-up are shown in Figure 1. The tensile test set-up consists of clamps, weight cups, and bucket container that are mounted on the aluminum frame. The width and height of aluminum frame are 450 mm and 850 mm, respectively. The weight cup has 53 g. The elongation of test pieces were measured by using the aluminum scale.
2.2. Experimental method

The tensile test was performed to examine the mechanical properties of the silicone rubber as the artificial skin. Seven test pieces have been used. The tensile test was carried out under the same conditions, for example, about the room temperature, loading time, and a kind of material of the test pieces.

Every test piece was clamped in top side as shown in Figure 1.B. The top side was fixed and the bottom side was pulled down with the load. The loading to test piece was continued until the test pieces broke. The elongations of test piece were measured after 10 sec for an every loading.

![Figure 1. Experimental setup for tensile strength](image)

**Figure 1.** Experimental setup for tensile strength

![Figure 2. Relationship between nominal stress and strain of silicone rubber used as artificial skin](image)

**Figure 2.** Relationship between nominal stress and strain of silicone rubber used as artificial skin
2.3. Finite Element Analysis (FEM) on mechanical properties of artificial skin

The FEA was performed in order to examine the mechanical properties of silicone rubber. Quadrilateral shell elements of 4-node were used as finite elements. The length, width, and thickness of test pieces were 60 mm, 30 mm, and 3 mm, respectively. Test piece model was divided to 200 elements. Six Degrees of Freedom (DOF) were clamped for an each node on the top tip of test piece. The loads were applied to the other tip of test piece. The magnitudes of forces were varied from 0.52 N to 15.60 N. Nonlinear analysis were carried out since the deformations are large.

![Figure 3](image)

Figure 3. Poisson’s ratio determined by comparing the calculated and experimental results

2.4. Identification of mechanical properties of artificial skin using experimental and calculated results

Figure 2 shows the relationship between nominal stress, $\sigma$ and strain, $\varepsilon$. The maximum nominal stress and strain were $9.7 \times 10^{-2}$ MPa and 2.0, respectively.

Figure 3 shows the relationship between Poisson’s ratio and strain. The Poisson’s ratios were determined by comparing the calculated and experimental results. The poisson’s ratio of silicon rubber based on calculation and experiment is 0.49.

3. Measurement of facial shape

3.1. Measurement system

The schematic representations of scanning system are shown in Figure 4. The experimental devices consist of the 3D red line laser, the Charge Coupled Devices (CCD) video camera, the PC, and the calibration panel with scale points to adjust the size of an scanned object. The position of scanned object is in front of the calibration panel with the distance of 1,000 [mm]. The positions of video camera and red line laser are parallel to each other and in front of the scanned object.

3.2. 3D Scanning method and results

Scanning process consists of three steps. In the first step, the object is calibrated in front of calibration panel. In the second step, photo image of the object is captured by using the CCD video camera. In the third step, the object is scanned by using the red line laser.

The photos and scanned images consist of three parts: front face, 45° right side, and 45° left side. The photos and scanned images were merged. The merged of three parts has bring out the precision of image result.
4. Making meshes of facial model

4.1. Meshing by scanned 3D facial data

Figure 5 shows the comparison of facial model between initial condition and final model.

The meshing was included analyzing the geometry model and optimizing the meshing in all the surface of elements. Meshing the facial model is determined by the shape object surface. The quadrilateral shell element was used in meshing face because of the best quality surface.

4.2. Optimization of meshes
The optimization of meshes was carried out to repair defective elements on the surface. The defective elements were caused by overlapping or disconnected elements. Therefore, the overlapping elements should be removed and the disconnected elements should be linked.

5. Calculated results of facial expressions using finite element analysis

Figure 7 shows the comparison between the calculated and real human facial expressions. Six facial expressions have been carried out in this study: happiness, surprise, sadness, anger, disgust, and fear.

Figure 6. Expressions for Happiness, Surprise and Sadness between real human facial expression and calculated results by using the action units
The directions and magnitudes of forces in calculated are the most important to follow the human facial expressions. The calculated results effectively showed the facial expressions like human.

6. Conclusion
Mechanical properties of silicone rubber have been identified by tensile test and FEA. The properties have been used in computational simulation for facial expressions using FEA. The calculated results effectively show the facial expressions like human.

References
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