Softness Measurement Technics by Indentation
For Elasticity Evaluation of Human Face Skin

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1. Introduction
Easy and low invasive measurement device is useful in effective evaluation of skin. There is palpation as one of the methods which knows the state of the skin simply. Here, the Hertzian contact theory [1] is one of the few of the methods to measure the state data. Although the contact theory has high reliability, it is known that the theory has a little applicable shape of specimens. Especially, the contact theory had difficulties to analyze thin specimens like skin. Then, the authors had extended the contact theory to analyze the thin specimens [2]-[3] and developed the devices which can measure Young's modulus of it.

In this paper, the portable device for measuring the elastic modulus of human skin is introduced to evaluate the skin state of human face. The extended theory is shown in advance of this introduction, and then the measured state and discussion are shown for verification of usefulness of the device.

2. Theory Extension on Measurement
The Hertzian contact theory can be applied to analyze elastic contact problems, and has fundamental solutions for some contact models. Here, on the contact problem of a plane body and a sphere, the following relation can be defined in force F and displacement δ by the theory.

\[ F = \frac{4}{3} \frac{E}{1 - \nu^2} \left( \frac{\delta}{2} \right)^{3/2} A \delta^2 \]

(1)

Here, \( \delta \) is the diameter of the ball indenter, \( E \) is the Young’s modulus, and \( \nu \) is Poisson’s ratio. \( A \) is a coefficient for simplification of the relation.

In the relation represented in Equation (1), the plane body has semi-infinite volume because of mathematical concept of the theory, and the applicability of its solution is restricted by the concept. Then, the relation of the Equation (1) is extended to represent the thickness effect of finite volume. The extended relation is shown with the coefficients \( B \) of finite thickness as follows:

\[ \hat{F} = A \delta (1 + B \delta)^3 = \hat{A} \delta^2 \]

(2)

Here, the coefficient \( B \) expresses the phenomenon in which plane specimen becomes hard seemingly by thickness like Figure 1.

Fig.1 If thickness \( h \) of plane specimen becomes small, the change of force \( F \) due to indentation becomes hard seemingly.

3. Softness Measurement of Face Skin
Here, the experimental result by the measurement device developed for human face is shown as one example of research results based on the theoretical technology indicated in former section. The device is designed in a small body so that it may be easy to have. The indenter diameter of this device is 3 mm, and the maximum indentation length is 6 mm. The maximum of indentation force is designed as 0.1N. The control of the device is carried out with MS-Windows PC and Young’s modulus is also calculated by the original software developed on MS-Windows.

Softness distribution of human face skin measured by the device is shown in Figure 2. The color contour expresses the numerical value of Young’s modulus, and red means high value and blue is low. Since a mouth and eyes could not be measured, they are the numerical values of 0.

Fig.2 Measured result of the Elasticity of face skin.

4. Conclusion
Introduced device can expect to be used for the investigation of human health condition, and the development of cosmetics.

References