Dynamic Viscoelasticity Properties Evaluation of Skin and Development of Dummy Skin for Safety Evaluation : Analysis of Deformation Behavior in the Depth Direction of the Skin

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Introduction

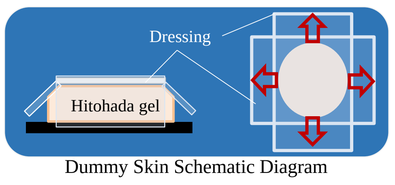
- In measures against pressure ulcers and safety evaluation of power assist robots, it is required to quantitatively evaluate the mechanical mechanism of the load on the human body.
- Because there are experiments that are difficult to perform *in vivo* from the viewpoint of ethics and reproducibility, dummy skin which is very similar in mechanical properties of living soft tissue such as skin and muscle is required.
- We have quantitatively evaluated the dynamic viscoelasticity of human skin in vivo in men in their 20s. Moreover, we were able to create a dummy skin whose hardness and dynamic viscoelasticity in the direction of shear on the surface closely resembled human skin in men in their 20s, by simulating the tension state of the epidermis against the simulated material simulating the hardness of human skin [1)].
- However, the skin is a hierarchical composite material composed of a plurality of materials of epidermis, dermis, subcutaneous tissue.[2)].


measures against pressure ulcers

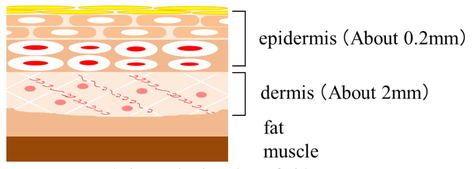

safety evaluation of power assist robots

The purpose of this research

In this study, we aim to develop dummy skin that simulates not only the surface but also the viscoelastic properties of human skin in the depth direction.



Dummy Skin Schematic Diagram



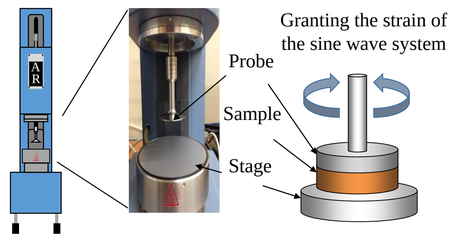
Schematic drawing of skin

Methods

Rheometer (AR550: TA Instruments)

The measurement procedure is shown below.
① Apply shear deformation to the sample using a probe.
② Measure the shear stress from the sample.
③ Dynamic viscoelasticity such as elastic component (storage modulus *G'*), viscous component (loss modulus *G''*), and loss tangent tanδ is calculated from the measured stress.
Here, the storage modulus G 'and loss modulus G "are the real part and the imaginary part of the complex elastic modulus G * representing dynamic viscoelasticity, respectively. The basic formula of dynamic viscoelasticity is shown below.

$$G^* = G'(\omega) + G''(\omega) \quad (1)$$
$$\tan\delta = G''(\omega)/G'(\omega) \quad (2)$$



Experimental conditions

	Frequency [Hz]	Strain [%]	Probe diameter [mm]	Pressing amount [mm]
human skin	0.4〜2.0	2	ϕ20, 40	2-6
dummy skin			ϕ20	

Experiment on human skin

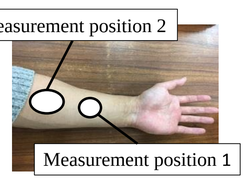
Materials

Human arm

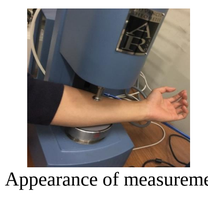
- The arm center part was taken as the measurement position 1, and the vicinity of the elbow as the measurement position 2.
- In order to reduce the influence of the edge of the probe, a probe with a diameter of 20mm was used as the measuring position 1, and a probe with a diameter of 40mm was used as the measuring position 2.
- Measurements were made in the muscle relaxed state.
- The stage temperature was 36 ℃ which is the same as the human body temperature.

Detail of subject

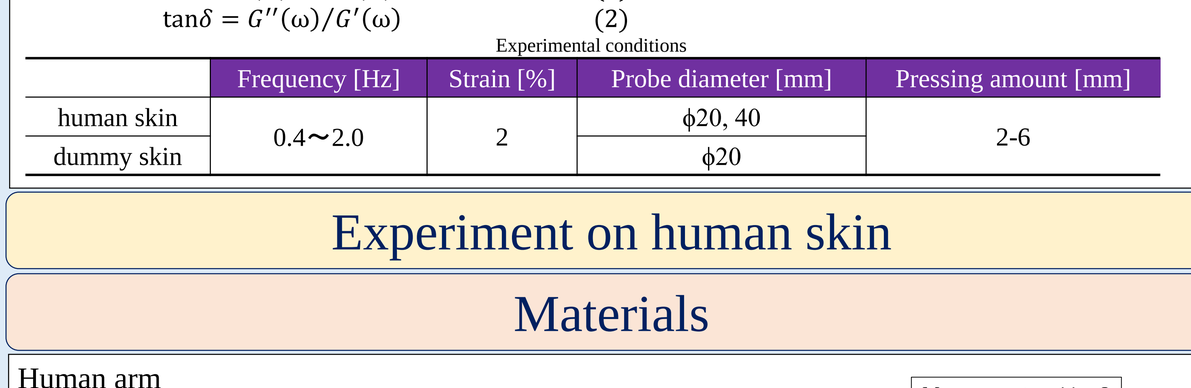
Gender	Age	Height [cm]	Weight [kg]	Dominant arm
Male	22	175	70	Left



Measuring part


Appearance of measurement

Results



Result of measurement position 1

Result of measurement position 2

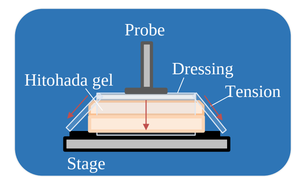
- *G'* and *G"* tend to increase as the pressing amount increases.
- In the range of the pressing amount of 3-6 mm, tanδ has almost the same value regardless of the measuring position and pressing amount.

Experiment on dummy skin

Materials

Dummy skin

- Hitohada gel (Asker C hardness 0, 5, manufactured by EXSEAL Co., Ltd.) which is a material having hardness equivalent to that of human skin, was used as a simulated skin material.
- As a pseudoepidermis, the state of the skin *in vivo* was simulated by applying tension to a dressing material (Permirol:Nitoms, Inc.) used at the time of treatment of pressure ulcer.
- Since human skin is composed of materials with various different mechanical properties, Hitohada gel of different hardness and thickness was laminated.



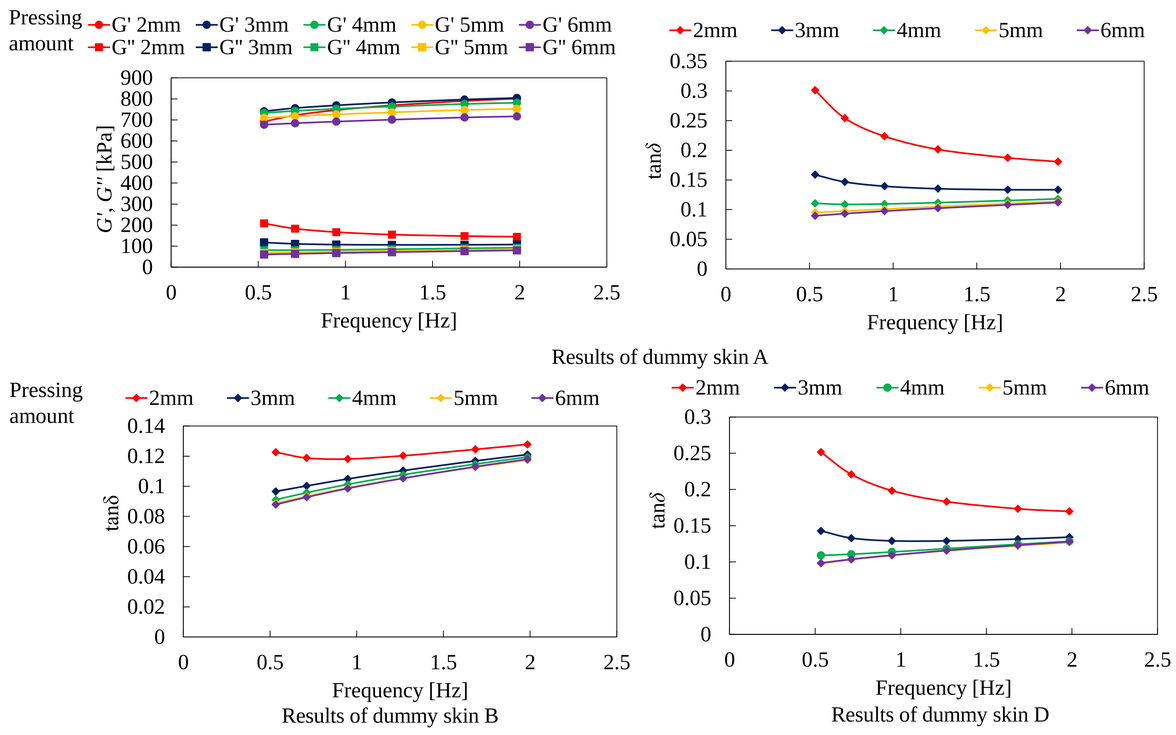
Dummy Skin Schematic Diagram

Dummy skin structure

Name	A	B		C		D	
Construction	Single layer	Stacking		Stacking		Stacking	
		up	under	up	under	up	under
hardness	5	5	0	0	5	0	5
thickness[mm]	26	2	10	3	10	3	20


Appearance of measurement

Results



- *G'*, *G"*, tanδ tend to decrease as the pressing amount increases.
- Due to the occurrence of slip, C could be measured only up to the pressing amount of 4 mm, but in the case of D with the under layer thickened, it was possible to measure up to 6 mm.
- The same tendency was observed for tan δ between A and D, B and C where the total thickness is equivalent.

Discussion

- In human skin, *G'* and *G"* tend to increase as the pressing amount increases, but since both increase at the same magnification, tanδ representing the their ratio is almost the same regardless of the measurement position and pressing amount. Therefore, in the current measurement region, the influence on the tanδ due to the pressing part is small, and the viscoelastic characteristics of the human skin can be quantified. However, because there is only one subject, it is necessary to verify whether the same tendency will also occur in other subjects from now on.
- In dummy skin, *G'*, *G"*, tanδ showed a tendency to decrease with increasing pressing amount, unlike human skin. This is considered to be due to the fact that the influence of the tension applied to the surface on the dummy skin decreases as the pressing amount increases. For that reason, structural measures other than simple lamination are necessary.
- In dummy skin, by changing the thickness of the whole, a change in the measurement result of tanδ was observed. Since this corresponds to the thickness of the arm in vivo, it is suggested that reproducibility of individual differences such as physique and sex is indicated by using this.

Conclusion

- In this measurement area, the influence on the tanδ due to the pressing site is small, suggesting the possibility of quantifying the viscoelastic properties of human skin.
- For the preparation of the dummy skin which simulates the characteristics in the depth direction, structural measures other than simple lamination are necessary.
- By changing the thickness of the whole, reproducibility of individual differences such as physique and gender was suggested.

Acknowledgments

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References

1) Nishio, Y., Ito, Y., Kishida, R., Kagiyama, Y., and Nemoto, T.: Dynamic Viscoelasticity Properties Evaluation of Skin and Making of Dummy Skin for Safety Evaluation, The Japanese Society for Experimental Mechanics, Vol.16, No4, (2016), pp.307-314.
2) Oka, H., and Irie, T.: Hihunanbusoshikimoderukanotamenoseitaiteisu (in Japanese), Society of Biomecanisms Japan, Vol.17, No.4, (1993), pp.216-222.