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Ultrasonic Viscoelastic Measurement of Inkjet Inks

Nobuaki Omata[1†] ([1]Highfequency Viscoelasticity Corporation)

1. Introduction

Ultrasonic physical property evaluation has been developed through theory and experiments since the 1960s. In industry, medical echography and non-destructive testing have developed as the main applications. Physical property evaluation, in comparison, does not seem to be mainstream. Although the speed of sound and attenuation rate cannot be considered physical quantities, if we consider them as viscoelasticity such as storage modulus and loss modulus, we can obtain values that can be used for numerical analysis. The target is a viscoelastic body such as elastomers and gels for solids, and ink and paint for liquids[1)]. In particular, the development of 3D printers using inkjet technology has been remarkable, and many media are considered to be viscoelastic bodies. In an inkjet head, a continuous pulse-like stress wave from a piezoelectric element propagates inside the chamber and ejects droplets through the nozzle. The viscoelasticity evaluation in this study uses a similar longitudinal wave perpendicular incidence, which is thought to enable viscoelasticity measurement in a frequency range close to the deformation speed during ejection. Here, we introduce the latest measurement results for commercially available inkjet printer ink, which has viscoelasticity close to that of water, which was the previous measurement limit.

2. Experimental method

The experimental device is a combination of multiple sensors with the HFR002 from High Frequency Viscoelastic Co., Ltd. By combining sensors, it is possible to know the viscoelastic properties in a wide frequency range of 0.5-20MHz. The L02 sensor has a band of 0.5-2MHz, the M01 sensor has a band of 2-7MHz, and the H01 sensor has a band of 5-20MHz. The sample ink is poured into the attached chamber Liq-mini (Fig. 1) or Liq-F and left in a thermostatic bath for 1 hour (Fig. 2). The measurement temperature is 25°C.

The samples used were dye-based Epson genuine products and aftermarket products, and Canon genuine products and aftermarket products. The samples were pigment-based Epson genuine products and aftermarket products, and all were magenta in color. Viscoelasticity measurements were calculated based on the propagation theory for vertically incident longitudinal waves. (For details, see Reference 1).)

Fig. 1 Liquid Adapter

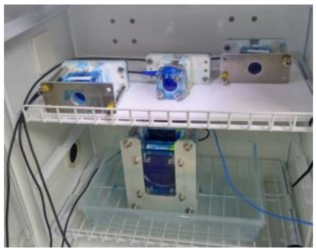

Fig. 2 Sensors in the thermal chamber

Table I shows the relationship between the longitudinal wave complex modulus $L*$ and other elastic moduli.

Table I Elastic modulus composition

Longitudinal elastic modulus	$L=K+4G/3$
Bulk modulus	$K=L-4G/3$
Young's modulus	$E=9KG/(3K+G)$
Shear modulus	G
Poisson's ratio	$\sigma=(3K-2G)/2(3K+G)$

3. Results

Figures 3 to 5 show the frequency characteristics of the storage modulus L', loss modulus L'', and loss tangent tanδ for each sample.

L'' tended to be smaller for genuine dye-based products manufactured by Canon than for Epson. For dye-based aftermarket products, the Epson-compatible type had a large deviation from the genuine product, and was closer to the Canon-compatible product. Pigment-based inks showed larger values than dye-based inks.

No significant differences were observed for L'.

4. Discussion

The high-frequency viscoelasticity of inkjet ink for printing is close to that of water, making it difficult to measure until now, but we believe that improvements in the precision of equipment and measurement skills have made it possible to compare the viscoelasticity of dye-based and pigment-based inks. It may also be possible to measure differences due to temperature changes and color tone (pigment). Both are thought to be due to the pigment particle size, concentration, dispersant, and medium properties. The differences between inks are such that L' and L'' have a different relationship.

5. Conclusion

Recently, inkjet printing has made a great leap from printing on paper to industrial modeling, such as 3D printers and printed electronics. In this process, issues such as high strain rates and increased viscosity are thought to have arisen.

It is expected that the high-frequency viscoelasticity evaluation method will be useful for improving inkjet ejection technology and optimizing the ink accordingly.

References

1) N. Omata, "Dynamic Viscoelasticity Measurement and Data Interpretation Examples" Technical Information Association, 2021, p. 25-41 [in Japanese].

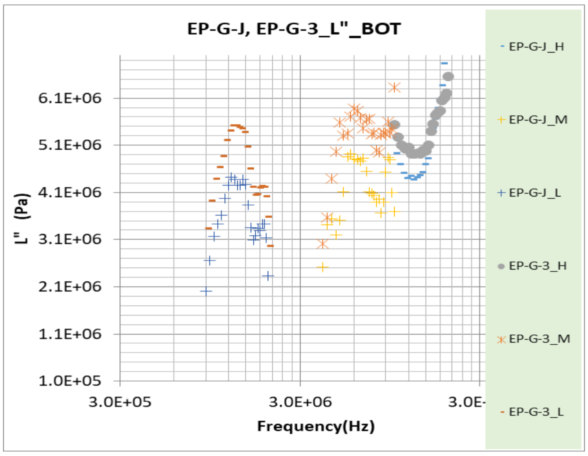

Fig. 3 Frequency dispersion of loss modulus L'' of EPSON genuine and aftermarket product of pigment-based ink

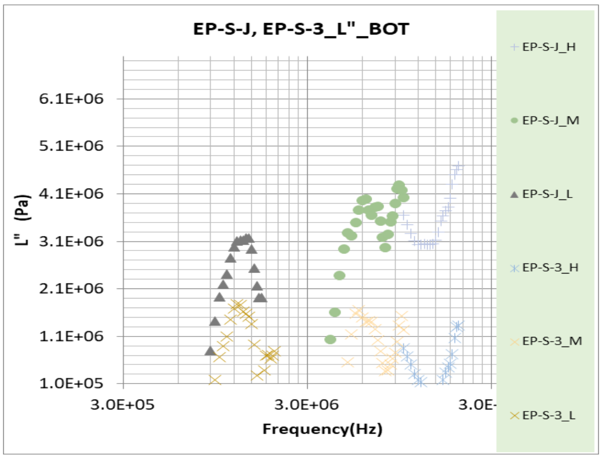

Fig. 4 Frequency dispersion of loss modulus L'' of EPSON genuine and aftermarket product of dye-based ink

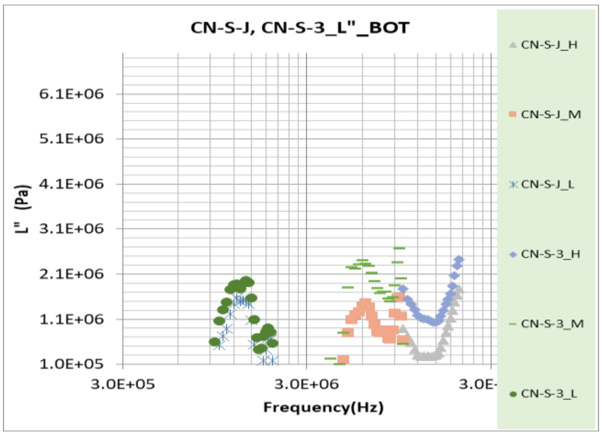

Fig. 5 Frequency dispersion of loss modulus L'' of CANON genuine and aftermarket product of dye-based ink