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Thesis Outline

Title

Numerical and experimental analysis on the evaporation of ethanol-water mixture droplet for inkjet technology
(インクジェット技術におけるエタノールと水の混合液滴の蒸発に関する数値と実験の解析)

An incomplete evaporation of ink droplet which leads to the product's degradation of inkjet printing technology, is currently the challenging issues among the inkjet printing researchers. Understand more about the principle and behavior of the evaporation of ink droplet is needed in order to minimize and prevent the loss of the product as well as provide a better and easier in the product quality control`s perspective. Nonetheless, it has to be noted that direct investigation of the evaporation of commercial ink material used with the inkjet printer is difficult due to several reasons such as high cost, difference compound in each brand available in the market. Therefore, water-based substance or water-mixture droplet is a better option in term of cost as well as the interpretation with all water-based ink.

Therefore, the overall goal of the present dissertation is to conduct both experiment and numerical analysis to investigate the evaporation of water-based mixture sessile droplet. Moreover, the objectives of the research are not only to measure the evaporation rate, but also to observe the other factors and circumstance that influence the evaporation of sessile droplet.

- **Chapter 1** describes the background and the outline of the research. The overall information of printing technology was firstly given; recently trend and potential its market, principle as well as types of 2D printer, and comparison between them. Next, inkjet printing, which was considered as the main application of this research, was fully described in detail. General information such as types, and ink materials of inkjet printer was provided. Then, issues and challenges that need to be tackled were point out. Incomplete evaporation of ink droplet causes a lot of following problems which lead to the decreasing of product quality. Therefore, the issue was narrowed down into the main objective of this research which is to perform the experiment and numerical simulation to investigate the evaporation of sessile droplet which was already informed by the title of the dissertation itself.

- **Chapter 2** describes the first phase of the study in this research. Calculating the evaporation rate of sessile droplet from different model: hemispherical and spherical shape model was aimed. To obtain the important parameters needed in each model, the Z-type Schlieren visualization technique and droplet measurement system are introduced to visualize the thickness of boundary layer and measure the droplet properties respectively. Numerical calculation as well as image processing associated with Schlieren visualization is provided. By balancing between the sensitivity of Schlieren system and the properties that represent water-based ink, ethanol-water mixture is used as a specimen. The validity and accuracy of using Schlieren system is also verified with a relation between light intensity and knife-edge position. The thickness of boundary layer as well as vapor area, which are influenced by the evaporation rate, are obtained and discussed. Meanwhile, radius,

height, and contact angle are also acquired. Finally, evaporation rate using each model is calculated and the comparison is performed.

- **Chapter 3** described the second phase of the study. The experimental scheme is similar to chapter 2, but humidity-controlled section and automatic droplet release system are added to the experimental set up to decrease the effect of the ambient properties on the experimental result as reported by the published literatures. Abel inverse transform together with Clausius-Mossotti and Lorenz-Lorentz equations are utilized in order to obtain the refractive index field as well as vapor concentration field evaporated from the sessile droplet. Effect of the humidity is also investigated by comparing the result between each relative humidity value. Moreover, numerical simulation carried out with OpenFOAM open-source code is introduced in this chapter. Continuity equation, Navier-stokes equation, and diffusion equation as well as boundary conditions associated in the calculation are provided. Finally, consistency of the results obtained from experiment and simulation is confirmed.

- **Chapter 4** described the third phase which is the final phase of the study. This chapter mainly focuses on the increasing of the consistency between the numerical simulation and experimental result. Activity coefficient factor is introduced and applied with the simulation processes. Effect of the mass lost due to the evaporation as well as diffusion inside droplet in the liquid phase are also considered. The results are compared between experimental result and each numerical simulation condition. Then, effect of each condition applied with the numerical simulation is also discussed as well as the effect of relative humidity on ethanol-water mixture droplet.

- **Chapter 5** summarizes the important conclusions in the research work contained in the dissertation. This chapter also proposes the potential future work that can be done to the unsolved issues and expand the usage limits.

- In addition, this dissertation also contains **two Appendices** to provide additional result and numerical simulation method used in this work.

In this dissertation, **References** section is placed at the end of each chapter to aid the readers