Fully integrated airflow visualization system for improved inkjet printing

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Abstract

Several new inkjet printing applications require high throw distances or high printing speeds. In such configurations, complex airflows occur in the gap between the printhead and the substrate, potentially jeopardizing the print quality by deviating the ink droplets. To better understand the airflow effects on the droplet's trajectories, a novel inkjet printing platform has been developed. The latter allows the full control of the different parameters, from the laser sheet intensity to the axis motion, to the fog generation, to the print head driving waveform. The system has been fully automatized and allow for large parametric study to be performed, key for unstable flows requiring for statistics.

Introduction

Driven by the digital revolution and the demand for personalized products, inkjet printing has evolved from being mainly used for graphical applications to a digital fabrication toolkit. Nowadays, functional ink drops are deposited on substrates of increasingly complex geometries (see Figure 1) [1].

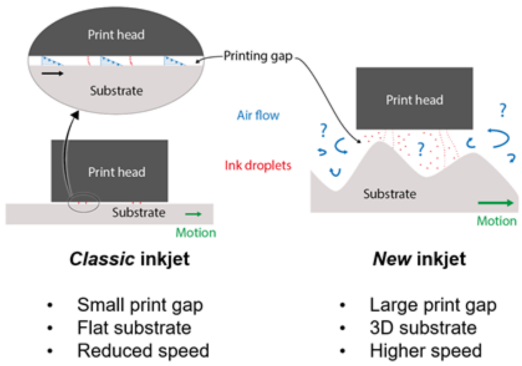

Figure 1. *Context of the project.*

As a result, the distance between the print head and the substrate is not always constant and can go up to several millimeters to avoid collisions or heat effects. This is in stark contrast with the classical working conditions of inkjet printing, where the print head is located 1-2 millimeters from a flat substrate. Furthermore, the industry is pushing for higher productivity, resulting in higher printing speeds. Today, the printing quality is dramatically compromised at higher throw distances and printing speeds by the appearance of severe drop misplacement effects.

The rationale for these undesired patterns (see Figure 2), usually referred as *wood-grain*, is the complex and unstable air flow that affects the drop trajectory for large gaps and high-productivity settings. In fact, when increasing the throw distance, the air flow produced by the jetted drops becomes increasingly important and interacts with the air flow induced by the relative motion between the print head and the substrate [2]. Furthermore, the latter is perturbed for larger gaps by external flow effects, as the transient ones induced by the varying curvature of a 3D object. Flying drops over long distances loose kinetic energy and are therefore deviated by these unstable eddy flows, eventually resulting in drop misplacement [3].

Figure 2. *Example of wood-grain effect. The printed image should be of uniform color.*

The aim of this project is to study the air flow and reduce its undesired effects on the drop trajectory to achieve higher print qualities at higher throw distances and higher speeds. To be able to visualize the airflow, a new sophisticated and versatile printing platform has been developed.

Materials and methods

A new versatile and automatized printing platform (see Figure 3) has been developed, including a dual camera system and a high-speed camera, a laser sheet generation system, a fog generation system, several possible print heads and a circulating ink supply system. Everything has been automatized and synchronized with the custom-made FPGA.

Figure 3. *Printing platform.*

Results

Beside the developed printing platform, which is a result itself, some very interesting flow visualizations could already be done and conclusions drawn. In addition to the well-known Couette and droplet-indued impinging jet flows, Poiseuille flow contributions due to pressure differences on both sides of the print head as well as inertial flow effects have been observed. The two latter contributions are mostly overlooked in the literature but can be either beneficial or detrimental to the stability of the flow [1, 4]. Furthermore, since more complex flow configurations have been studied, very interesting airflows have been identified (e.g. vortex shedding behind the print head for low confinements). The effect of the printing gap, printing speed, interleave printing, transient phenomena, have been investigated in this study.

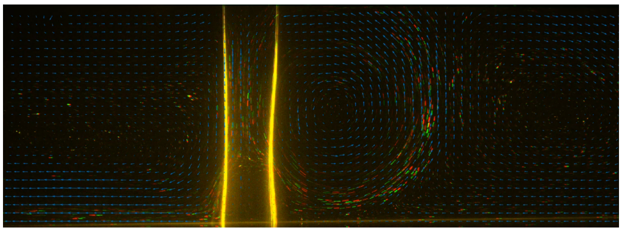

Figure 4. *Example of measured airflow field for* 0.3*m/s printing speed,* 4.5*mm throw distance and* 5 *pL droplets at 600 dpi.*

Conclusions

The key asset of the platform, where all subsystems have been developed internally, is the full control of the different parameters, from the laser sheet intensity to the axis motion, to the fog generation, to the print head driving waveform. The system has been fully automatized and allow for large parametric study to be performed, key for unstable flows requiring for statistics.

References

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Author Biography

Johannes Renner studied mechatronics with specialization in automation technology at the Secondary Federal College of Engineering in Vienna, and mechanical engineering as well as mechatronics at the Bern University of Applied Sciences, where he worked after graduation in 2007 as scientific assistant and later on as scientific officer for the Institute of Print Technology. In 2013 he joined the iPrint institute. Johannes has gained over 15 years of experience in applied research with the focus on inkjet technology and is contributing to many of iPrint's inkjet-related projects.

Jonas Maturo has a Bachelor's degree in Mechanical Engineering and a Master's degree in Biomedical Engineering. In 2018, he started working at iPrint, where he worked on various lab projects like designing and testing microfluidics on print heads, studying droplet aerodynamics, developing printed electronics, and investigating the transport of drop-encapsulated objects. Since 2023, Jonas has been actively involved in the family-owned business, focusing on tailored solutions in mechanical development.

Vincent Schneuwly obtained a bachelor degree in electrical engineering at the School of Engineering and Architecture of Fribourg. He then worked at iPrint while pursuing his Master's degree in Embedded Systems, that he obtained in . Vincent currently works at iPrint as R&D engineer in electronics.

Benoît Sahli holds a Bachelor degree in Mechanical Engineering from the School of Engineering and Architecture of Fribourg. After graduating in 2019, he gained experience as Mechanical Engineer in the field of hydro-electric power plant. Benoît started at iPrint as R&D Engineer in additive manufacturing, where he designed, built, programmed and tested custom 3D printers.

Yoshinori Domae studied Mechanical engineering and joined Seiko Instruments Inc. in 2006. Working in Seiko I Infotech division, he was in charge of design and development of wide format inkjet printers. After moving to SII Printek division in 2011, he was the Project Leader and Chief Designer of printhead R&D. Then he invented and designed RC1536 inkjet printhead which was disruptive new recirculation printhead for some industrial inkjet applications. After that, he moved to France where he had worked as the Technical Manager for all industrial inkjet applications in EMEA, since 2014. In 2019 he joined iPrint in Switzerland, and started his activities especially for inkjet technology and innovation.

Gioele Balestra holds a Master degree in Mechanical Engineering from ETH Zurich and a PhD from EPFL. He joined iPrint in 2019 to develop new digital deposition techniques and since July 2020 he is in charge of the applied research and educational activities of the institute and competence center.