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Instrumentation System for Liquid Drop Impact and Evaporation

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Abstract

Droplet impact and evaporation presents a complex physical process worth investigating not only from a fundamental research perspective but also in its potential for industrial application. However, in order to extract usable data from this small scale, fast phenomenon in the lab producing a droplet of repeatable volume and position as well as accurately track and collect the data (temperature, impact, evaporation) is essential in order to extract reliable and study worthy results. This procedure forms the basis of this project.

Contents

1	Introduction	1
2	The Problem	1
2.1	Existing Process	1
3	Proposed Solution	2
3.1	Base Deliverables	2
3.2	Stretch Goals	3
3.3	Timeline	3
4	Evaluating your Solution	3
5	Resource Requirements	3
5.1	Facilities and Tools	3
5.2	Health and Safety	3
5.3	Budget	4
6	COVID-19 Alert Level Management	4

1 Introduction

The investigation of droplet impact and evaporation is an area of experimentation of interest and application to various industry. Such as milk powder spray drying, ink jet printing, and applications of evaporative cooling. This project will continue on from a previous instrumentation setup, evaluation its shortcomings, and design the next generation to improve the reliability and usability of the collected data. This report proposes a series of subsystem (re)designs to the mounting, droplet dispensing, and data collection to achieve the above goal. The project will be evaluated based on a produced report on the prior generation.

Below is a milestone based timeline, deliverables, resources and budget requirement as well as COVID-19 adaptation statement.

2 The Problem

This project is concerned with the development of an instrumentation rig for the study of droplet impact and drying. It is primarily/initially motivated by the powdered milk production process, specifically the behaviour of the drying and collision of concentrated milk droplets. Furthermore, the research, and developed method and procedure can be applicable to various industries.

To effectively investigate the behaviour, a variety of aspects can be tracked and characterised during a microscale equivalent lab process, from differing temperatures, substrates, volume, and concentrations.

Currently, there is an existing platform for the dispensing of droplets and data capture using high speed cameras and other various sensors. It has limitations due to manual control of starting the cameras capture and temperature capturing as well as requiring the operator to position and dispense the droplet by hand.

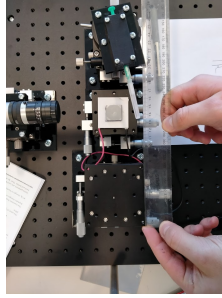
This project will, therefore, focus on the development of the third generation of this platform with the aim to design and integrate various new subsystems and evaluate their performance against the existing platform with the main project goal of having a more stable, repeatable testing platform that will not only yield more usable data but streamline the experimental process.

2.1 Existing Process

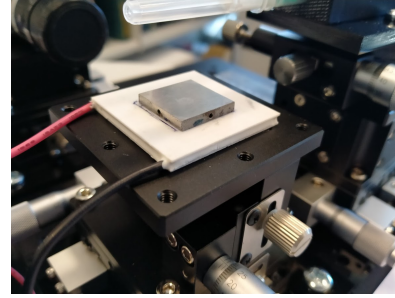
The current procedure as of the project beginning is a manual process. There is currently no securing bracket of any kind for the substrate sample and heater stack, the cameras and other sensors are turned on one by one and most importantly the droplet is rotated above a mark in the substrate and dispensed via syringe by hand.

The droplet then falls onto the substrate, monitored by 2 high speed cameras (profile and overhead) and the temperature of the substrate is measured via an embedded thermocouple camera a time series waveform of the experiment.

We hypothesis that this method contributes a large amount of variation into the collected data that could be masking the parameter space of interest, and limiting the granularity at which conclusions can be drawn about the process of impact and evaporation.



(a) Full Top View



(b) Substrate Stack close-up

Figure 1: Previous Rig Assembly (bar top camera)

3 Proposed Solution

The primary driving principle for both the design and evaluation of this next generation is a focus on *increasing the reliability of the process by designing new and/or improving existing subsystems of the rig.*

To be able to quantify success in that aspect and evaluations of current systems results is needed to identify its short comings. Therefore, one of the first steps is to produce a report detailing such aspects.

- Repeatability of dispensed droplet parameters (position, volume (size), contact angle) and correlate and/or see how the variation in these parameters affects the observed temperature profile and physical behaviours of the droplet throughout the evaporation process.
- Identify other sources of variation, such as humidity etc and their weight of influence (whether perusing a solution is worthwhile)
- Compare with similar solutions in the literature to gain more insight into required design consideration and constraints.

Alongside this, the first step is a mechanical design of a bracket and clamp assembly to hold and centre an aluminium heatspreader, Peltier heater, and substrate to the sample stage (fig 1).

From this, the primary effort will go into the droplet dispensing stage. Possibly integrating an electronic pipette and motorised stage XY rotation to address the consistency problems. Constraints that will have to be overcome are the reduce volume capacity (syringe: 12-15ml to max 10ml) and refilling from a reservoir.

The above represents the base deliverables, but the project may be extended with data collection automation and synchronisation, and more environmental monitoring and control.

3.1 Base Deliverables

- Mechanical designs to hold, centre, and clamp the substrate stack together (1-2 weeks).
- Produce evaluation document based on generation 2 performance (2-3 weeks)
- (Main) Improved Droplet Delivery stage; dispensing control, motorised stage.

3.2 Stretch Goals

- Synchronous data collection, i.e. cameras, temperature, droplet
- Measure and control environmental factors

3.3 Timeline

	Trimester 1															Trimester 2													
Milestone	1	2	3	4	5	6	Break	7	8	9	10	11	12	Study Period	Break	1	2	3	4	5	6	Break	7	8	9	10	11	12	S
Write project proposal																													
Last Gen Evaluation and Design Research																													
Sample Stage mechanical design																													
Implement prototype design of Droplet stage																													
Write preliminary report																													
Present preliminary report																													
Refining Droplet Stage																													
Stretch Goals																													
Final report draft																													
Final report																													
Submit project snapshot																													
Final presentation																													

4 Evaluating your Solution

To evaluate the success, the produced evaluation document on generation 2 will serve as the primary comparison. Each subsystem; mechanical brackets, droplet dispensing, temperature measurements will be tested individually to quantise their contribution and as a gradually integrated whole.

The preliminary evaluation criteria (subject to change with the discretion of the previous generation analysis) include consistency and repeatability of the following:

- Dispensed volume
- Impact characteristics (centre, angle, etc)
- Uncontrolled temperature variation

5 Resource Requirements

5.1 Facilities and Tools

- Labs AM219 and LB207
- Computer with SolidWorks, LabView, and other data processing tools
- Electronics Test bench (PSU, signal generator, scope etc)
- Access to fabrication workshop

5.2 Health and Safety

The project does not necessitate

- Lab Induction (LM207)
- Peltier Heaters
- Basic electronic safety

5.3 Budget

It is worth noting that the instrumentation platform is largely constructed with all its major components, and most needed parts for the design and development of the project are already present.

Given this, the project has estimated a budgetary restriction of \$400.

- \$200 to cover workshop manufacturing costs of mechanical designs
- \$200 for the purchase of stepper motors and auxiliary components, PCB design and manufacture and all other electronic component costing.

6 COVID-19 Alert Level Management

The combat and alleviate the effects of increased alert levels, the collaborative design and physical work (bracket design and manufacture etc) will be front loaded or at the very least prepared for. In the event of restricted access to the university, the project can shift to tasks more remote friendly with some ease. Such as more development of data collection software and syncing as well as EDA design of say, the motorised stage circuitry. Meetings can be remotely undertaken without effort and all files, material and supporting information is being stored and synced via git and other remote storage solutions.

If the circumstance allows it, equipment may also be taken home and work can be done at an at-home workshop.