Blood & Heat

Morphology and Spreading Behaviour of Blood Droplets Impacting an Inclined Pre-Heated Surface

Authors
Mees Bouwman[1], Kuba Karkus[3],
Mariëlle Kortlever[3], Jimme Wolberink[2]

(1) Applied Physics student
(2) Archaeology student
(3) Forensic Investigation student

Tutors
J. Brons, N. Zeijen, E. Snippe, M. Steenhuisen,
(Client) M. Eversdijk, (Client) R. Gelderman

Client
Loci Forensics B.V.

Saxion University of Applied Sciences | Faculty: Life Science, Engineering and Design (LED), Enschede

SAXION UNIVERSITY OF APPLIED SCIENCES

INTRODUCTION

The interpretation of bloodstains becomes challenging in crime scenes, altered by fire [1]. High temperatures can significantly impact blood behavior. Due to limited research, forensic conclusions are hard to make.

In this study, the interaction of blood with heated surfaces at different temperatures, heights, and angles is examined, to give a better understanding of blood behavior in fire-related crime (arson) scenes.

The goal of this project is to get a better understanding on how different surface temperatures influence the morphology and spreading behaviour of a blood droplet under varying impact velocities and angles.

THEORY

Blood consists approximately of 50% water, and plays a crucial role in the morphology of blood drops on heated surfaces. The typical boiling curve of water can be used for blood, only at slightly higher temperatures [2].

Blood behaves as a shear-thinning, non-Newtonian fluid due to red blood cell interactions. During droplet impact, however, shear rates are sufficiently high for blood to behave as a Newtonian liquid. The spreading dynamics are therefore governed by inertia, viscosity, and surface tension, quantified by the dimensionless Reynolds and Weber numbers.

Bloodstains are almost always elliptical. The impact angle can be determined from the stain geometry using:

$$\sin\alpha = \frac{W_{max}}{L_{max}} \qquad (1)$$

For the trajectory reconstruction of a ballistic droplet, the spreading factor is generally used in combination with a model based on either the capillary, viscous or both regimes.

METHODOLOGY

Drop impact experiments were conducted with sheep blood kept at 37 ◦ C, dropped on a ceramic tile.

1. The tile is heated to the surface temperatures: 23, 90, 120, 160, 230 ◦ C .
2. The tile is set to the wanted incline: 0, 15, 30, 60 ◦
3. A blood droplet with a volume of 15.0 µL and a diameter of 3.06 mm is pipetted from different heights: 30, 60, 90 cm
4. A photo is taken of the blood droplet immediately after impact and after 45 seconds.
5. Steps 1-4 are repeated two times, all possible combinations are measured three times.

An ellipse is fitted allong the leading edge of the bloodstains. Performed by a self-written MATLAB function.

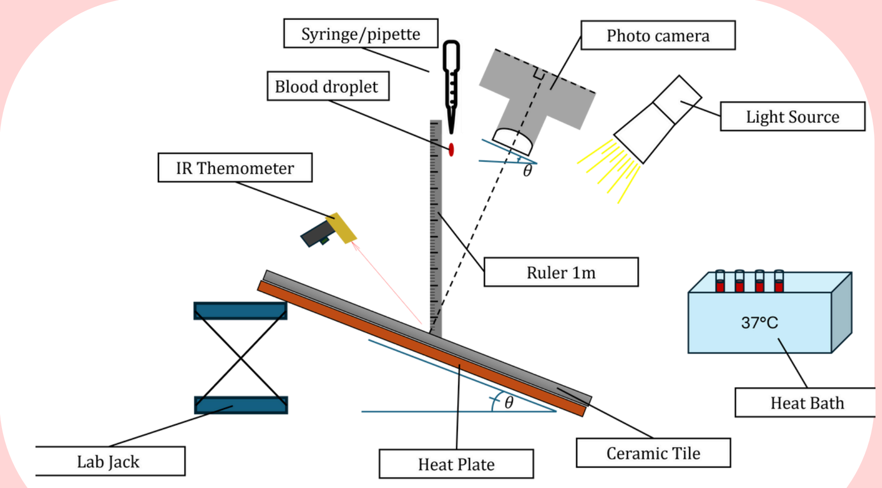

Figure 1: Schematic visualization of the setup used during the experiments.

Photo's of blood droplets at five different surface temperatures 45 seconds after impact, using an inclination of 60° and a drop height of 90 cm

23 °C | 90 °C | 120 °C | 160 °C | 230 °C

DROP SPREAD

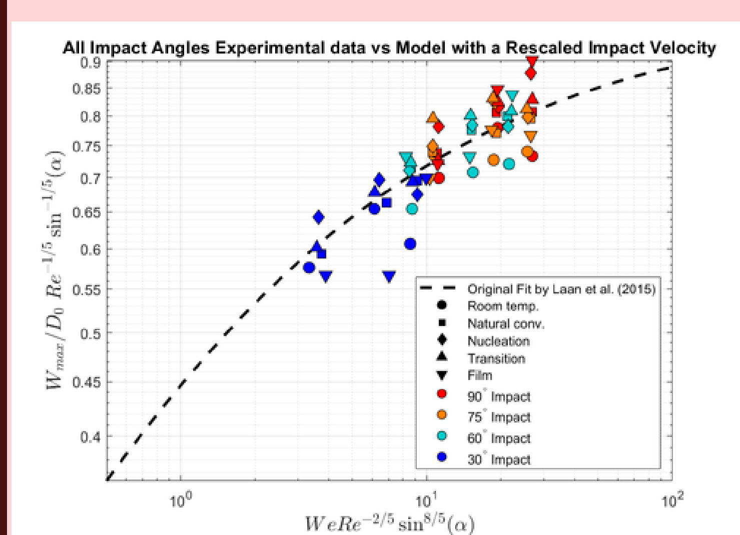

Figure 2: Experimental data fitted to the model by Laan et al. (2015) by tuning the impact velocity.

- Spreading model proposed by Laan et al. (2015)[3]
- Good agreement with experiments, R^2= 0.71
- Velocity fitting constant C_v= 0.8035 (A = 1.24 from Laan)

$$\frac{W_{max}}{D_0} = Re^{1/5} \cdot \frac{P^{1/2}\sin\alpha}{(A + P^{1/2}(\sin\alpha)^{4/5})} \qquad (2)$$

$$V_0(h) = C_v\sqrt{2gh} \qquad (3)$$

- Numerically solving Eq. 2 for the impact velocity
- Shows good agreement with the red dotted lines calculated with Eq. 3
- Small sample size (n = 3) significantly affects peak visibility
- All data points are therefore added cummulatively to the histogram

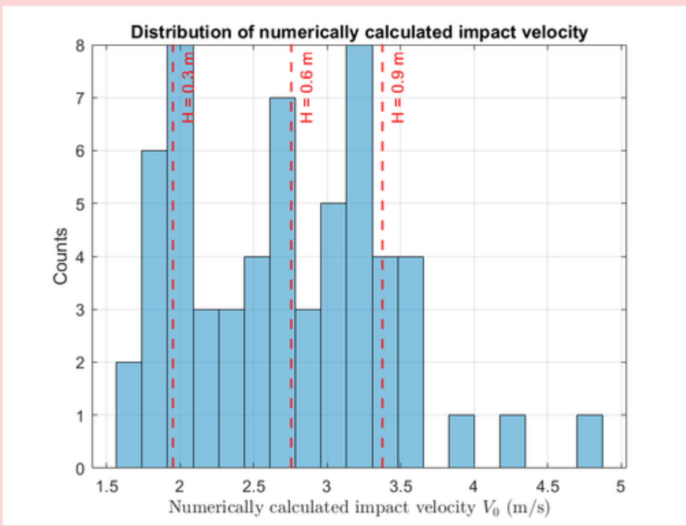

Figure 3: Distribution of the calculated scaled impact velocities and the fitting parameter A.

IMPACT ANGLE

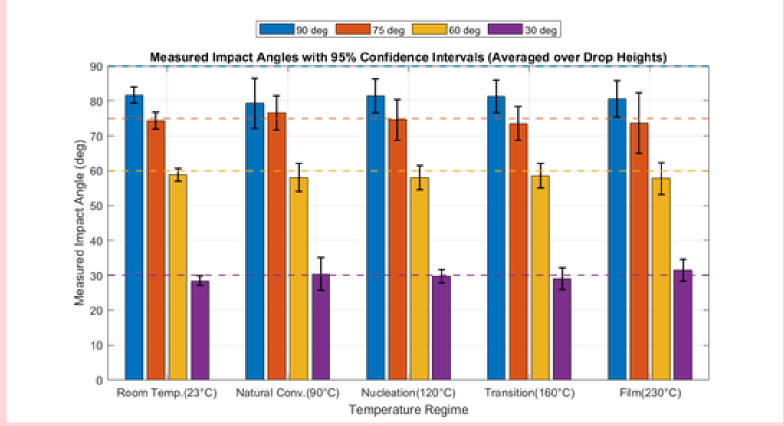

Figure 4: Measured impact angles averaged over the repetitions and drop heights.

- Error bars cross the 'true impact' angle for all cases with reasonable precision except 90°
- Error bars for 90° and 75° mostly overlap
- This indicates no significant difference between these impact angles

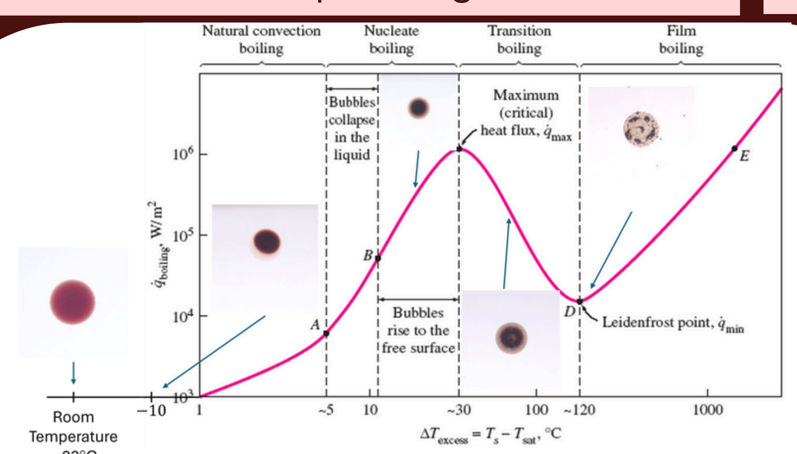

Figure 5: Summary of the typical appearance of a bloodstain.

NUANCES AND IMPLICATIONS

- Estimating the blood drop trajectory purely based on stain geometry does not capture all information [4].
- Information is lost when the drop reaches the maximal therminal velocity
- Fluid spreading models have a strict limit which is not talked about enough

- Sample size (n = 3) is to small
- Experimental setup was not efficient
- Pipetting method was inconsistent
- Heating area on the heating plate was not homogeneously distributed

For more information, scan this QR-code

REFERENCES

[1] Belinda Bastide, Glenn Porter, and Adrian Renshaw. *"The effects of heat on the physical and spectral properties of bloodstains at arson scenes"*.
[2] Bethany A. J. Larkin and Craig E. Banks. *"Preliminary study on the effect of heated surfaces upon bloodstain pattern analysis"*.
[3] N. Laan. *"Impact of blood droplets"*.
[4] Taylor & Francis. *"Principles of Bloodstain Pattern Analysis"*.