Numerical Study of Hydrodynamics of Droplet Train Impingement Process using CFD Analysis

– Jayaveera P. Muthusamy, et al.

Jayaveera P. Muthusamy, Taolue Zhang, Jorge Alvarado
Department of Mechanical Engineering

Introduction

The objective of this study is to investigate the hydrodynamics due to high frequency micro-droplet train impingement on a pre-wetted solid surface. Numerically, the ANSYS Fluent CFD tool was used to simulate the droplet train impingement and heat transfer process. Computationally expensive Volume-of-Fluid (VOF) multiphase model was used to perform the 3D numerical simulations with mesh sensitivity study, Explicit/Implicit model study, time step sensitivity study and many other numerical studies to fix all appropriate boundary conditions using TAMU's ADA cluster. 10 HPRC cores were used for continuous 25 days in order to get a steady state solution. The computational domain has 20 million cells with complex physics such as interface capturing, surface tension effects, conservation of mass, momentum and energy and other relevant equations.

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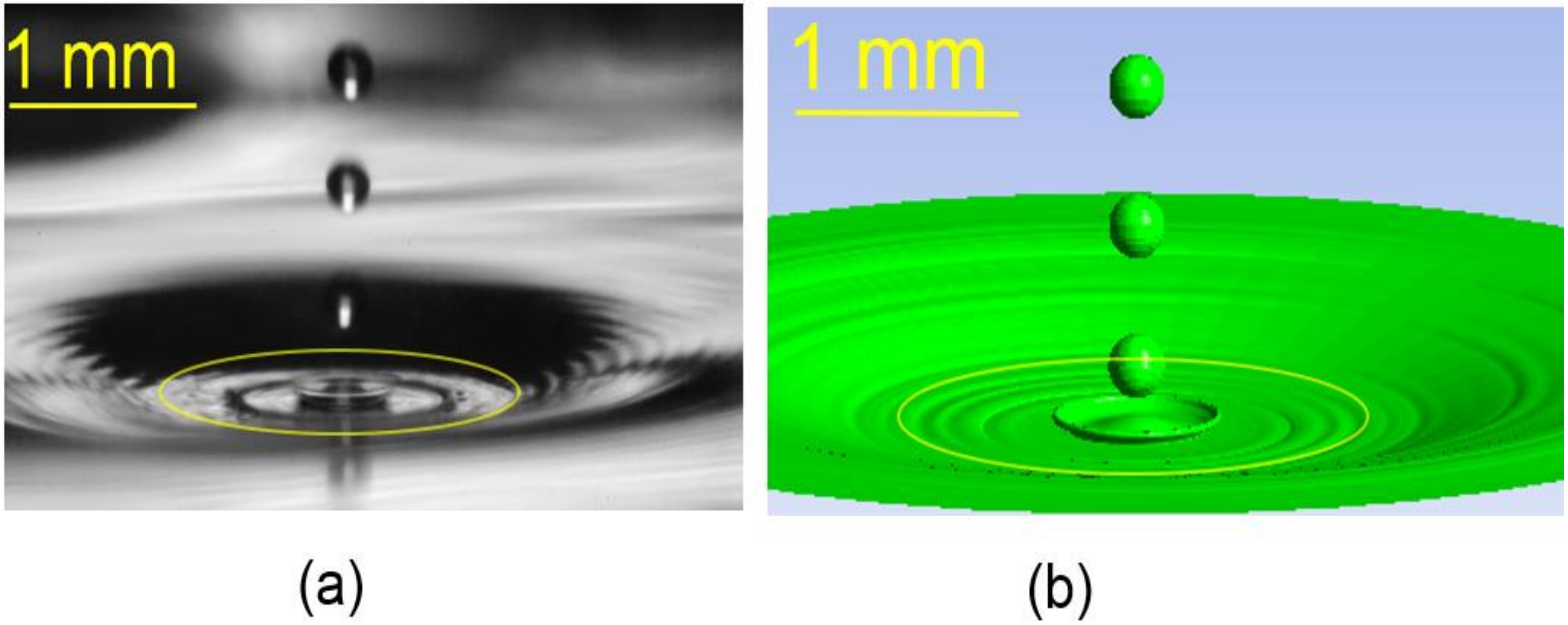
Droplet Train Impingement: Hydrodynamics



(a) Experimental and (b) numerical droplet-induced crown in 3D

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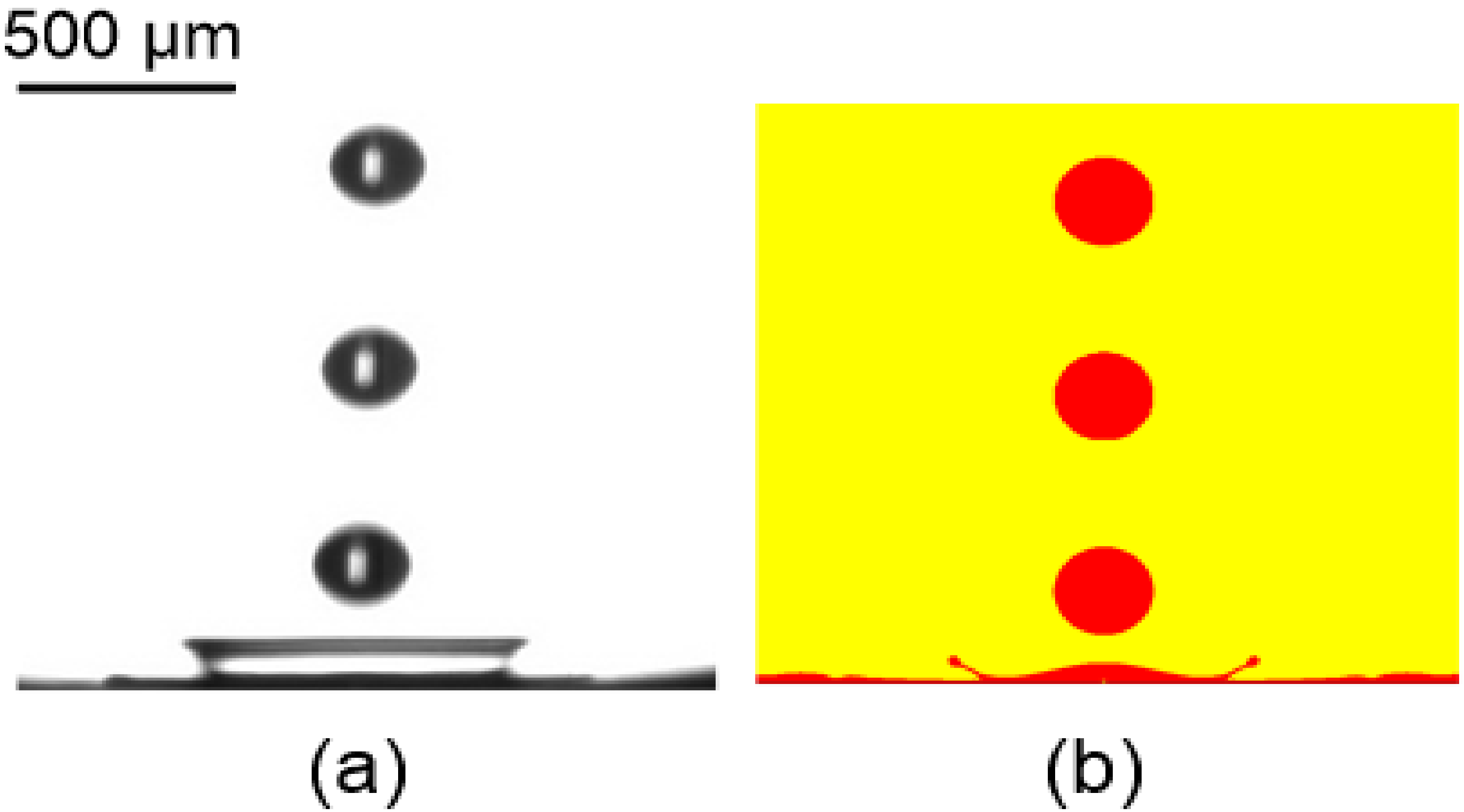
Droplet Train Impingement: Hydrodynamics



(a) Experimental and (b) numerical droplet-induced crown

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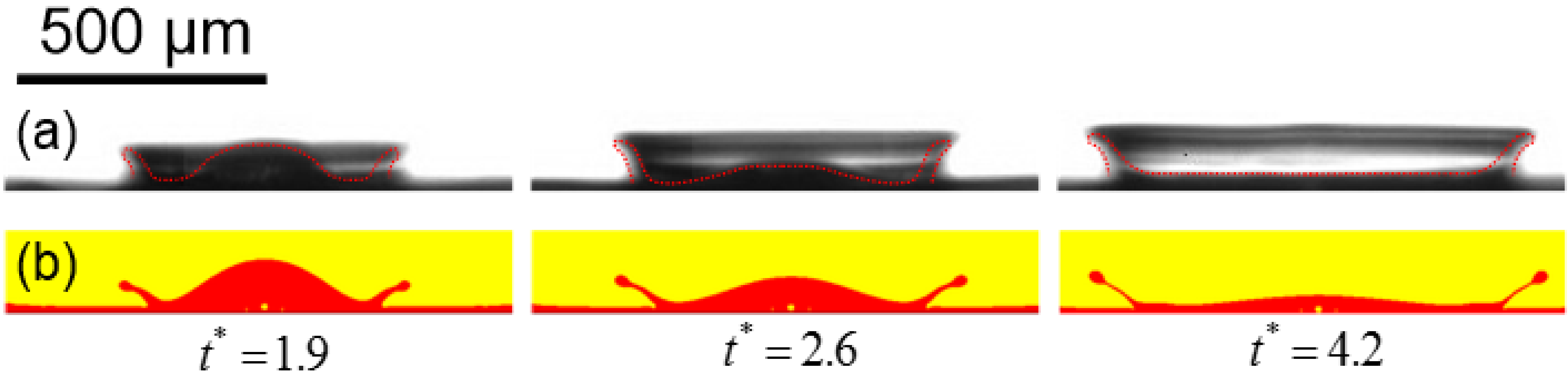
Droplet Train Impingement: Hydrodynamics



$t^* = 2\pi ft$, ($t^* = 0$, at the first contact between droplet and liquid film)

(a) Experimental and (b) numerical transient crown propagation dynamics

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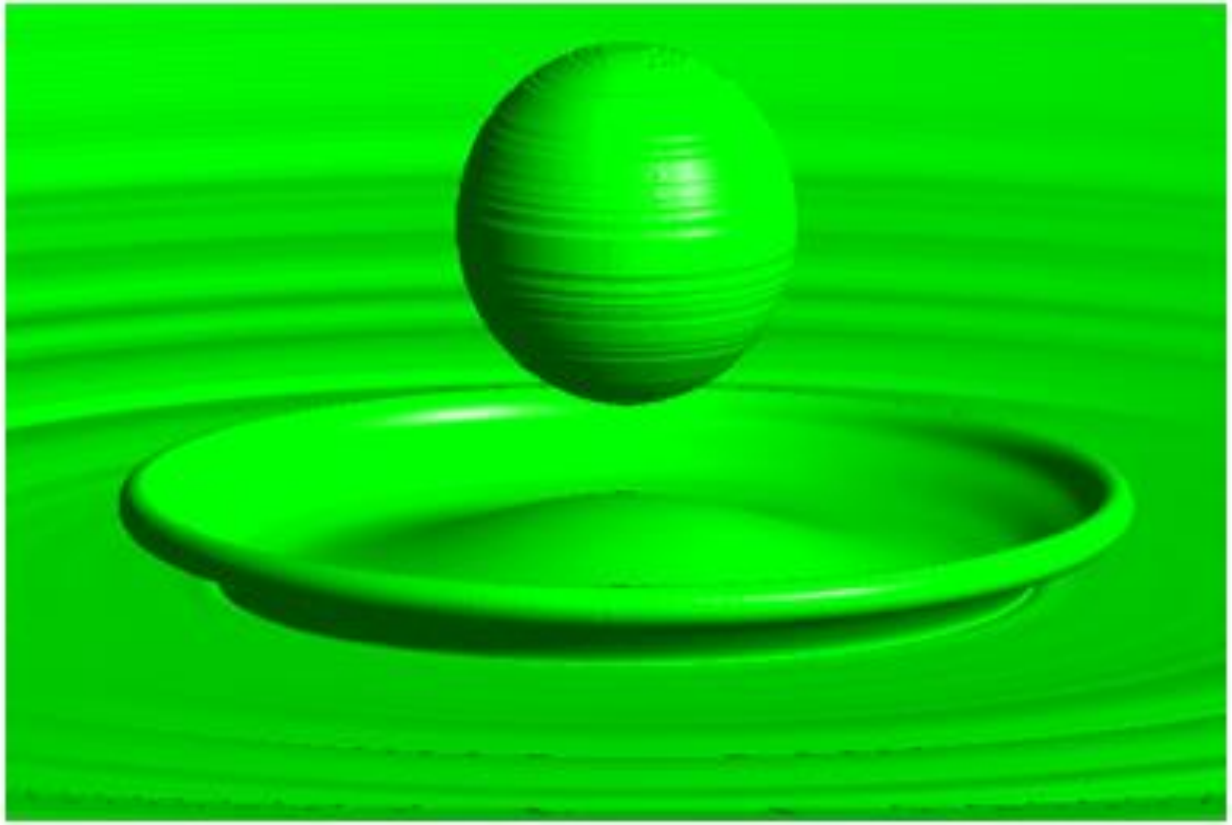
Initial Spot Crown Formation: Numerical



Droplet induced crown at the instant of initial spot formation

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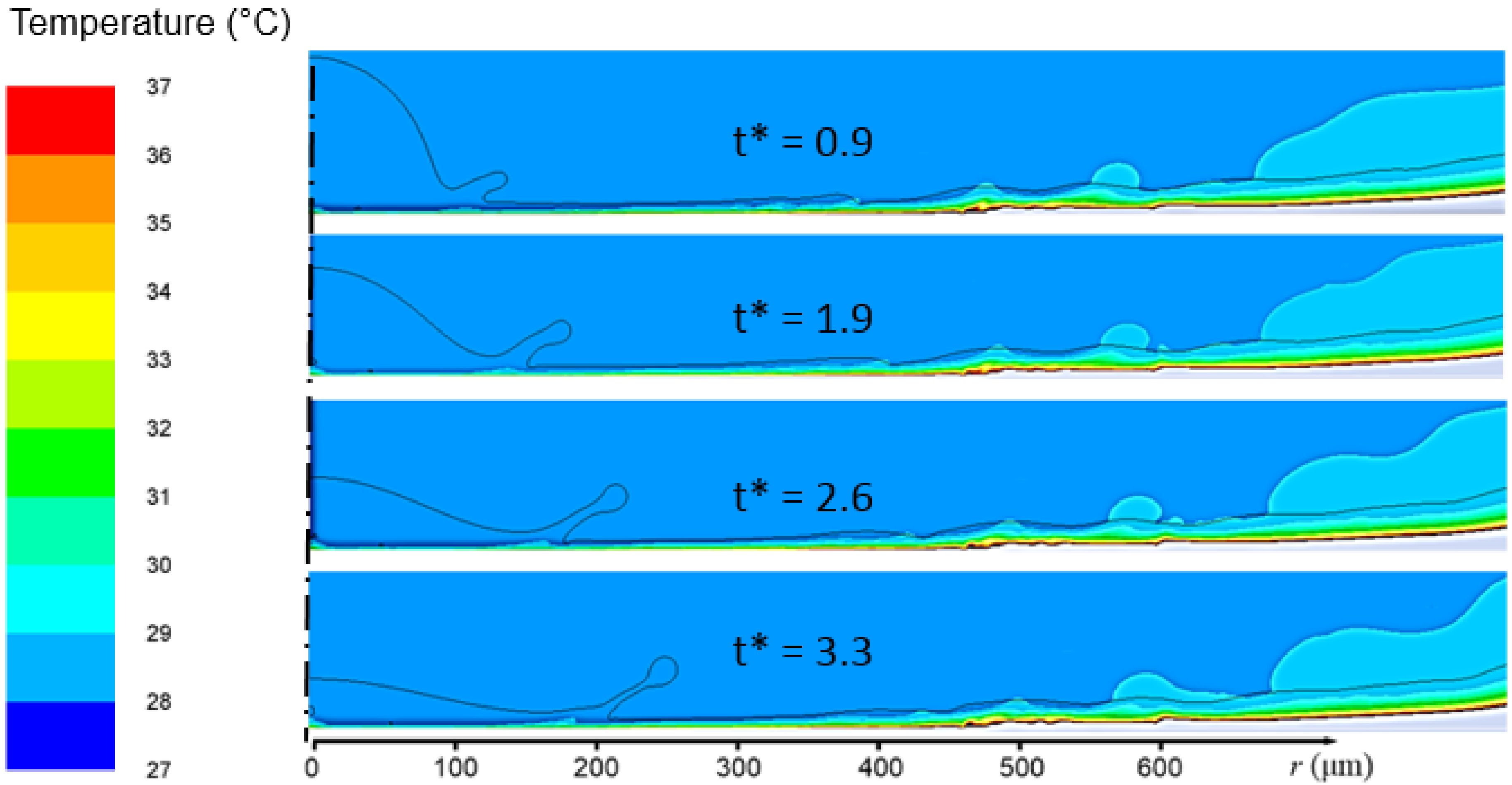
Heat Transfer:



Instantaneous temperature field at a heat flux of 3 W/cm^2 and We = 280

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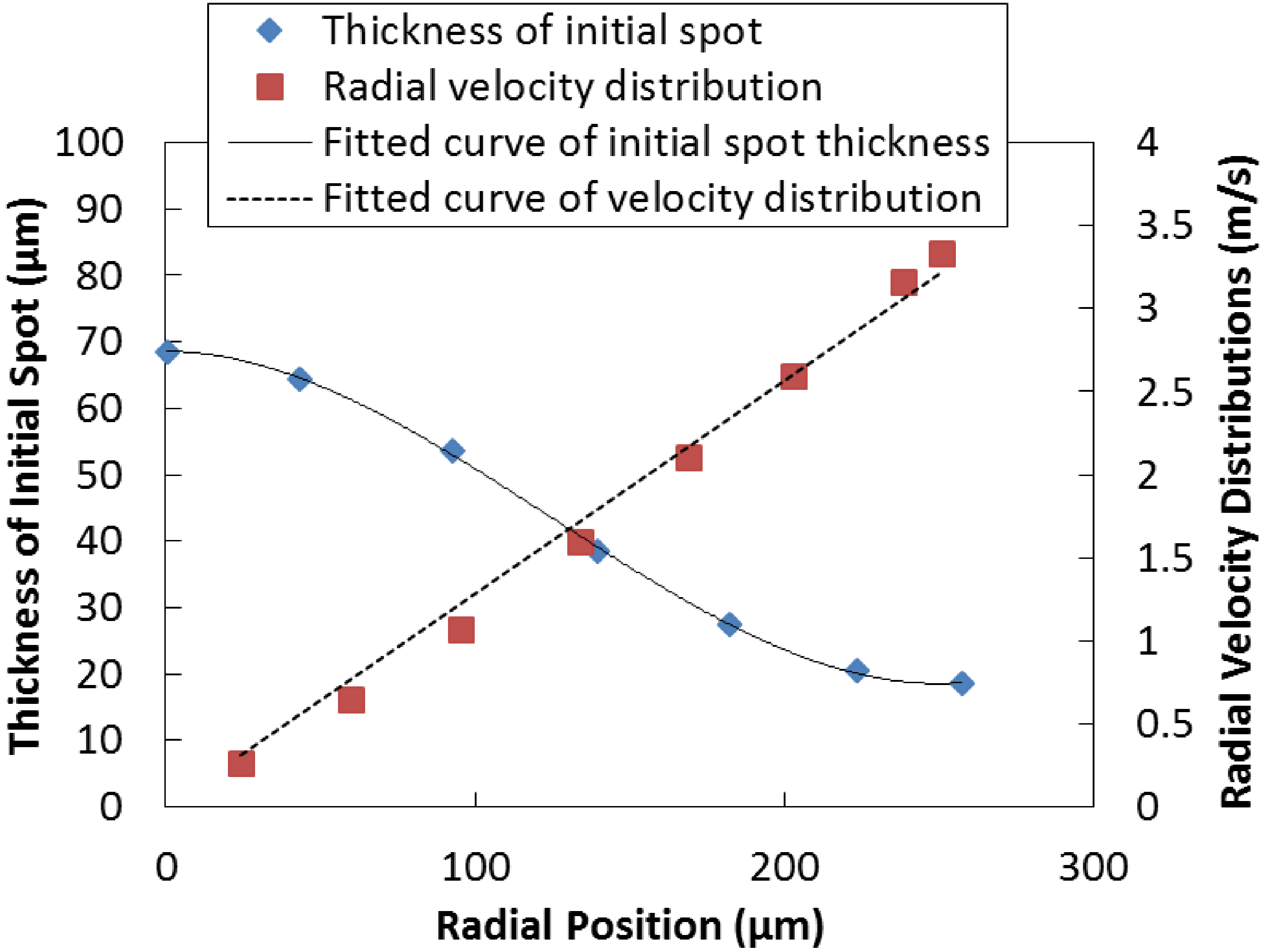
Initial Spot Thickness and Velocity:



Original Assumptions

$$\bar{u}(r) = \begin{cases} V_d, & 0 \le r \le R \\ 0, & r > R \end{cases}$$

$$\bar{h}_{spot} = h_0$$

Our Observations

$$\begin{cases} \bar{h}_{spot} = 3h_0 \\ u(r) = \dfrac{r}{R} \cdot V_d \end{cases}$$

Our Proposed Model

$$d^*_{c,base} = \left[\frac{\sqrt{2} V_d^{1/2}}{6^{1/4} \left(\bar{h}_{spot}\right)^{1/4} \pi^{1/2} d_d^{1/4} f^{1/2}} \right] \left(t^*\right)^{1/2}$$

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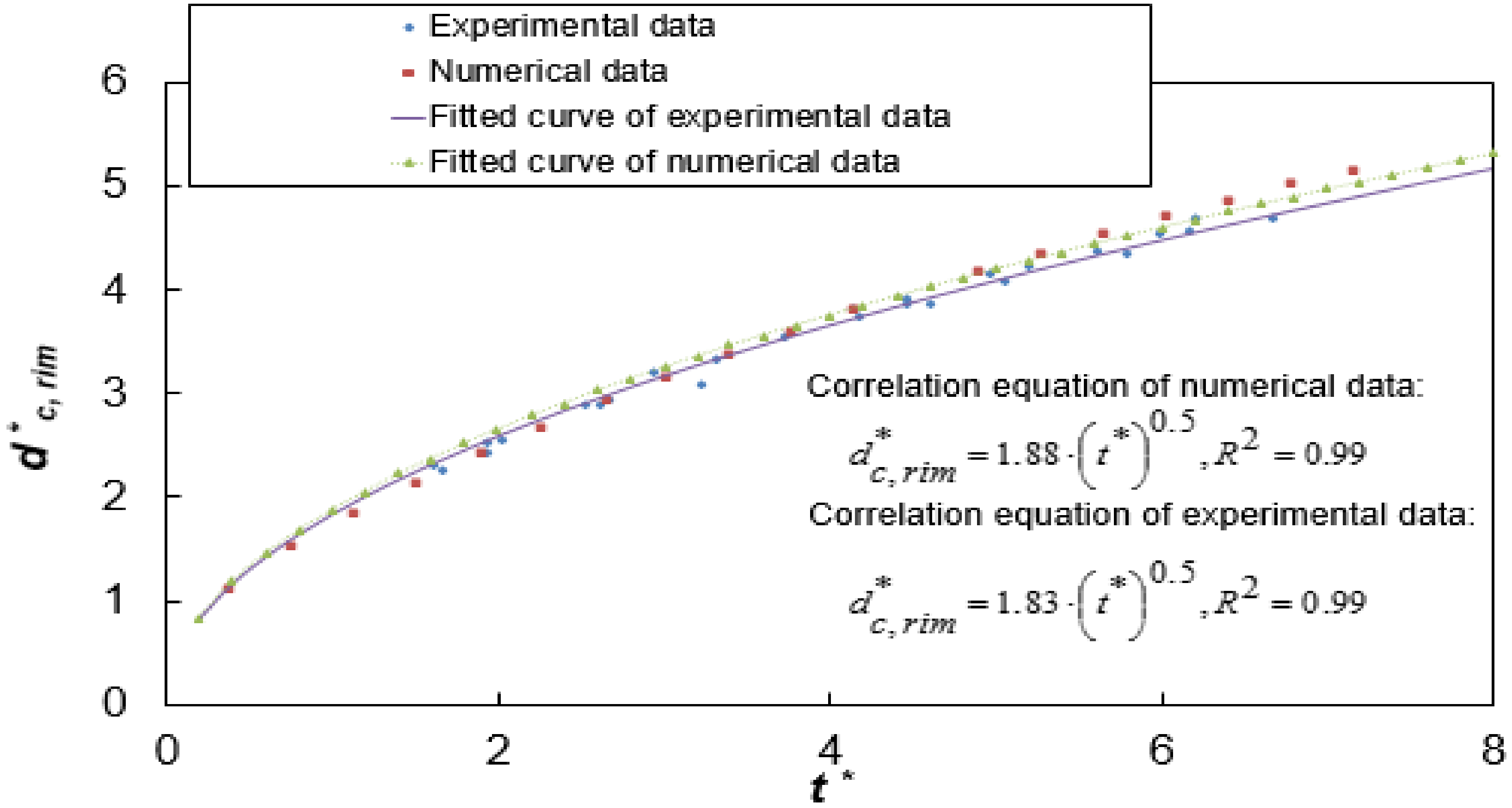
Crown Propagation Comparison:



Numerical and experimental transient crown propagation curves

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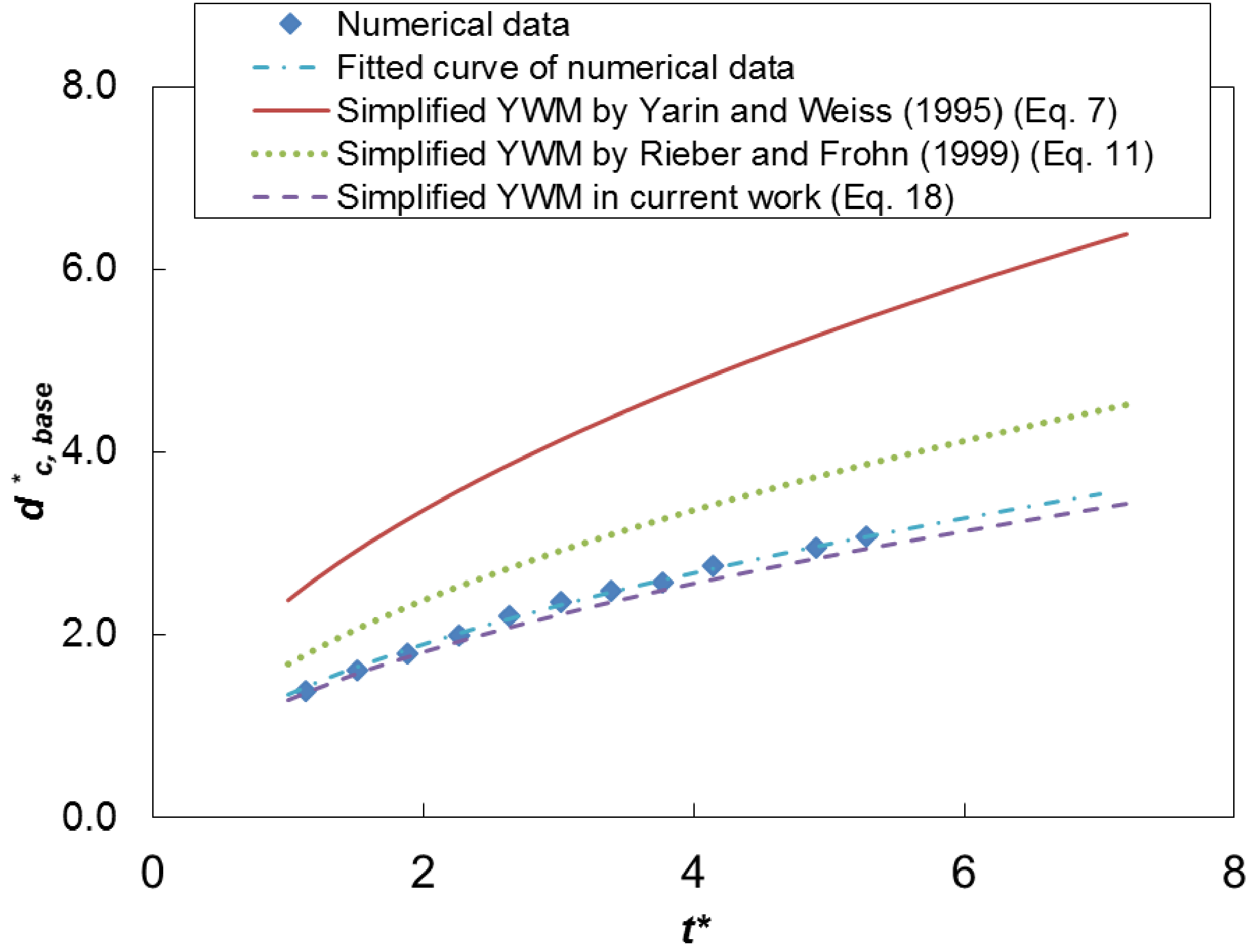
Revised Crown Propagation Model:



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Observations:

- Good agreement between the numerical and experimental crown rim propagation curves
  - Necessity of selection of right computational models
  - Considerable time and cost saving for future studies
- Proposed a revised Yarin and Weiss Model (YWM) with improved accuracy with the help of numerical results using TAMU's HPC
- Numerical studies with proper validation and HPC resources can reduce the lead time with least number of experiments

Acknowledgement:

Thanks to TAMU's HPC which was a key to complete this work on time.