Non-linear Dynamics of Confined Leidenfrost Droplet: A Video-based Analysis

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Leidenfrost drops are extremely mobile and thus display unusual properties. To better understand the complex dynamics of Leidenfrost drops confined by a spherical surface and its mechanism as a noise-induced chaos system, we used time-series analysis and state reconstruction methods to find the quantitative chaotic markers of droplet motion. Water drops ranging from 0.02 ml to 0.6 ml colored with food dye were released individually on heated concave spherical surface of aluminum containers less than 7.5 cm from the center. The motion of drops was then recorded using a camera and analyzed by computer vision programs to obtain the position-time data of drops. Each time series was analyzed for its trajectory, frequency domain, maximum Lyapunov exponent (MLE), and recurrence using computer algorithms. Abrupt changes in the direction of oscillation were found at low amplitudes. Trajectories of drops show a dissipative quasi-periodic motion. Brownian motion was observed when the oscillation amplitude was below 20 mm. The negative slope of spectral density (-25.2 dB per decade) in the frequency spectrum indicates Brownian noise. Positive MLE and embedding dimensions of 3 were found. Repeating structures and short diagonal lines in the recurrence plot were observed. This study shows that the motion of confined Leidenfrost drops displays low-dimensional chaos, and two phases of motion with different properties can be distinguished by the amplitude of the oscillation. This research presents a novel experiment for the field of non-linear dynamics, especially noise-induced chaos, and allows future applications in mass transfer in the industry. Theoretical mechanical models and forecast algorithms will be investigated in future studies.

Awards Won:
Third Award of $1,000