Particle-level dynamics of clusters: Experiments in a gas-fluidized bed

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Abstract

The clustering is critical to understanding the multiscale behavior of fluidization. However, its time-resolved evolution on the particle level is seldom touched. Here, we explore both the time-averaged and time-resolved dynamics of clusters in a quasi-2D fluidized bed. Particle tracking velocimetry is adopted and then clusters are identified by using the Voronoi analysis. The time-averaged results show that the cluster hydrodynamic parameters depend highly on the cluster size and the distance from the wall. The number distribution of the cluster size follows a power law ($\tilde{}n_c{}^{-2.2}$)) of the percolation theory except for large clusters (n_c>100). The time-resolved analysis shows that the cluster coalescence can be simplified as a collision between two inelastic clusters, during which the net external force is roughly zero, and a snowplow model is proposed to predict its energy loss, ΔE ˜ $t^{3/2}$. The cluster rupture is suggested to be caused by increasing torque.

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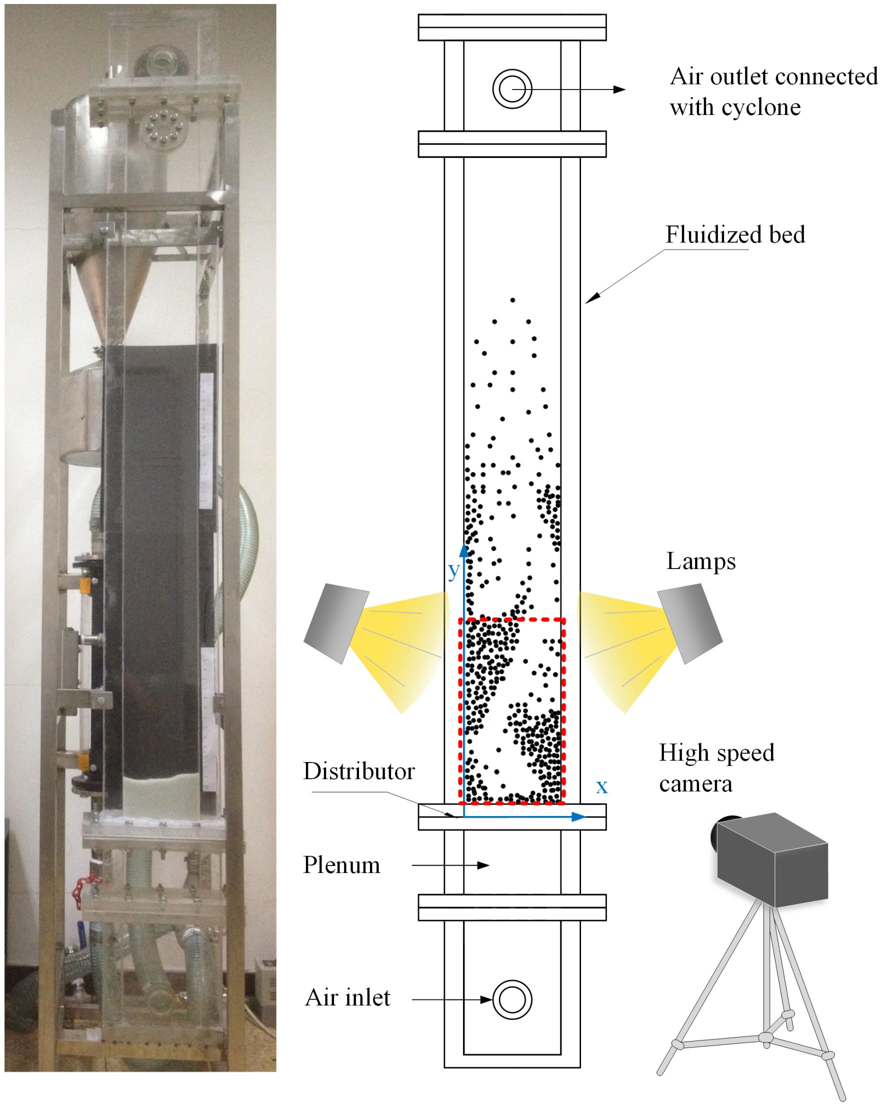
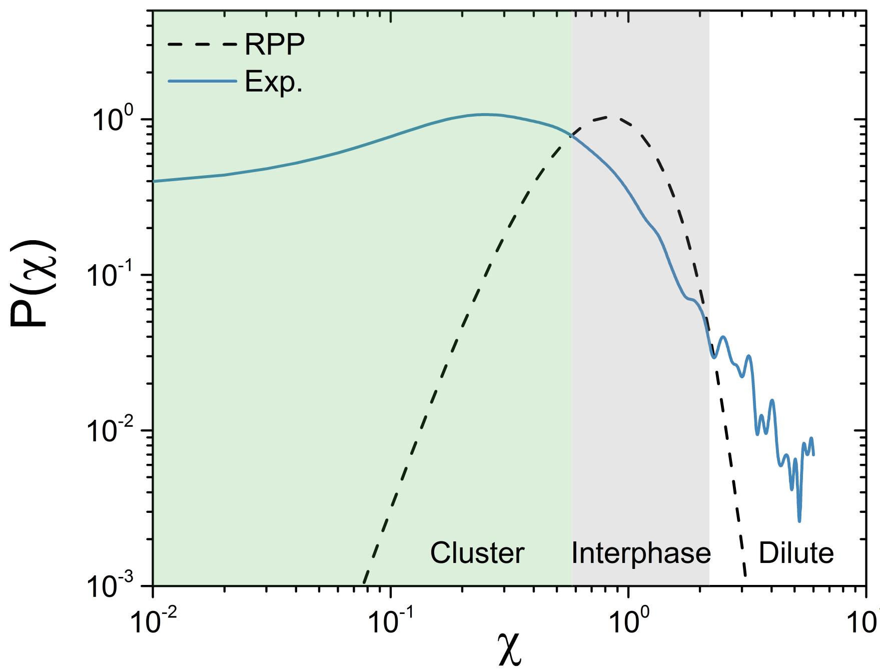
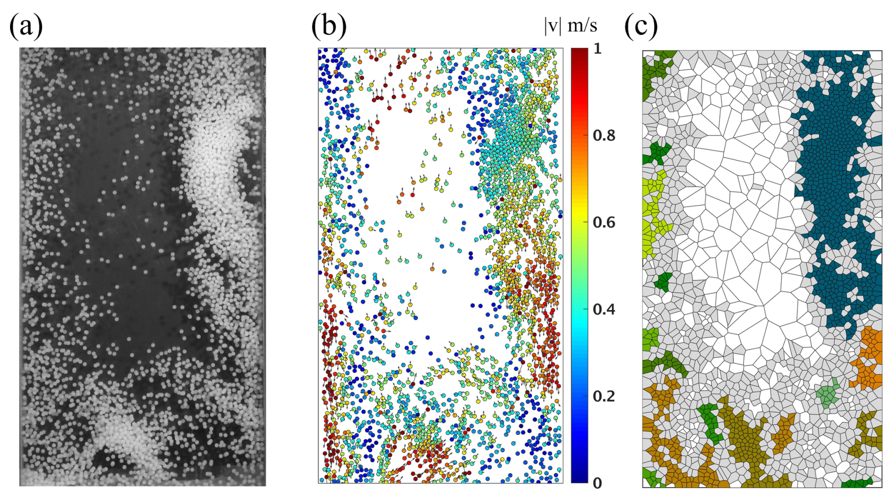
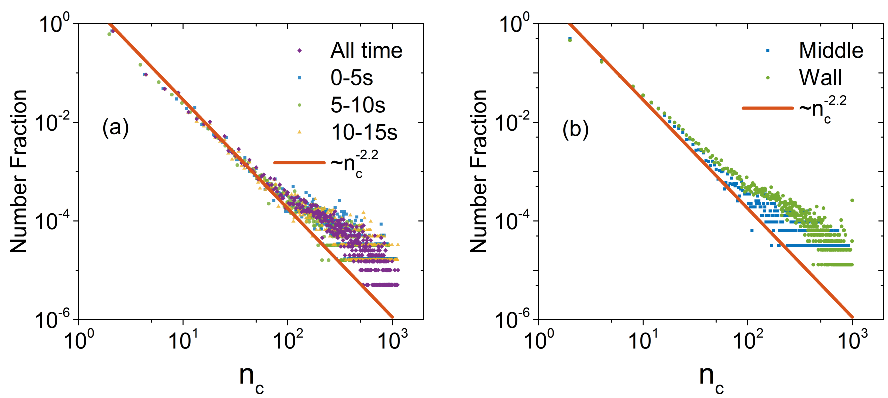
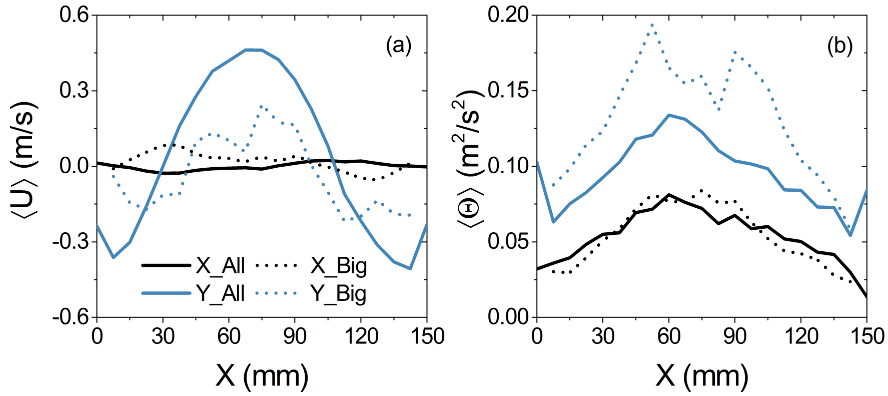
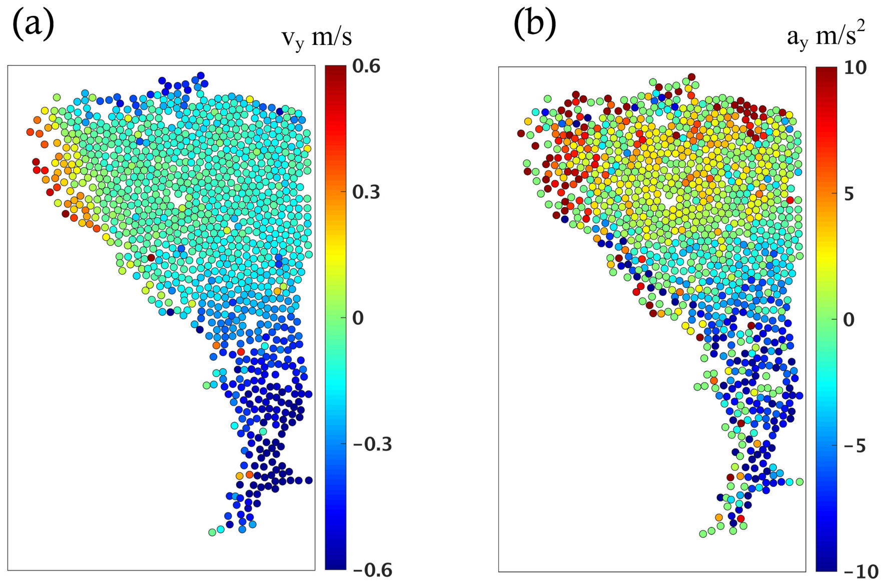

Air outlet connected
with cyclone
Fluidized bed
Lamps
y
x
Distributor
High speed
camera
Plenum
Air inlet

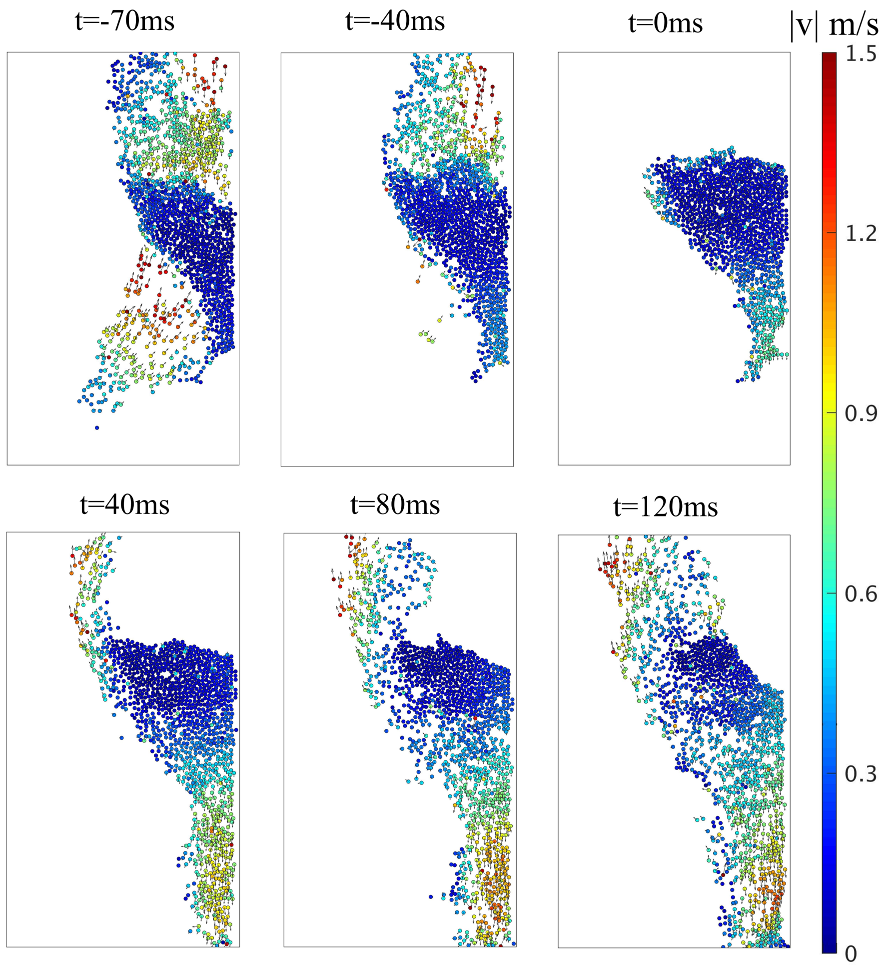

RPP
Exp.
P(χ)
χ
Cluster
Interphase
Dilute

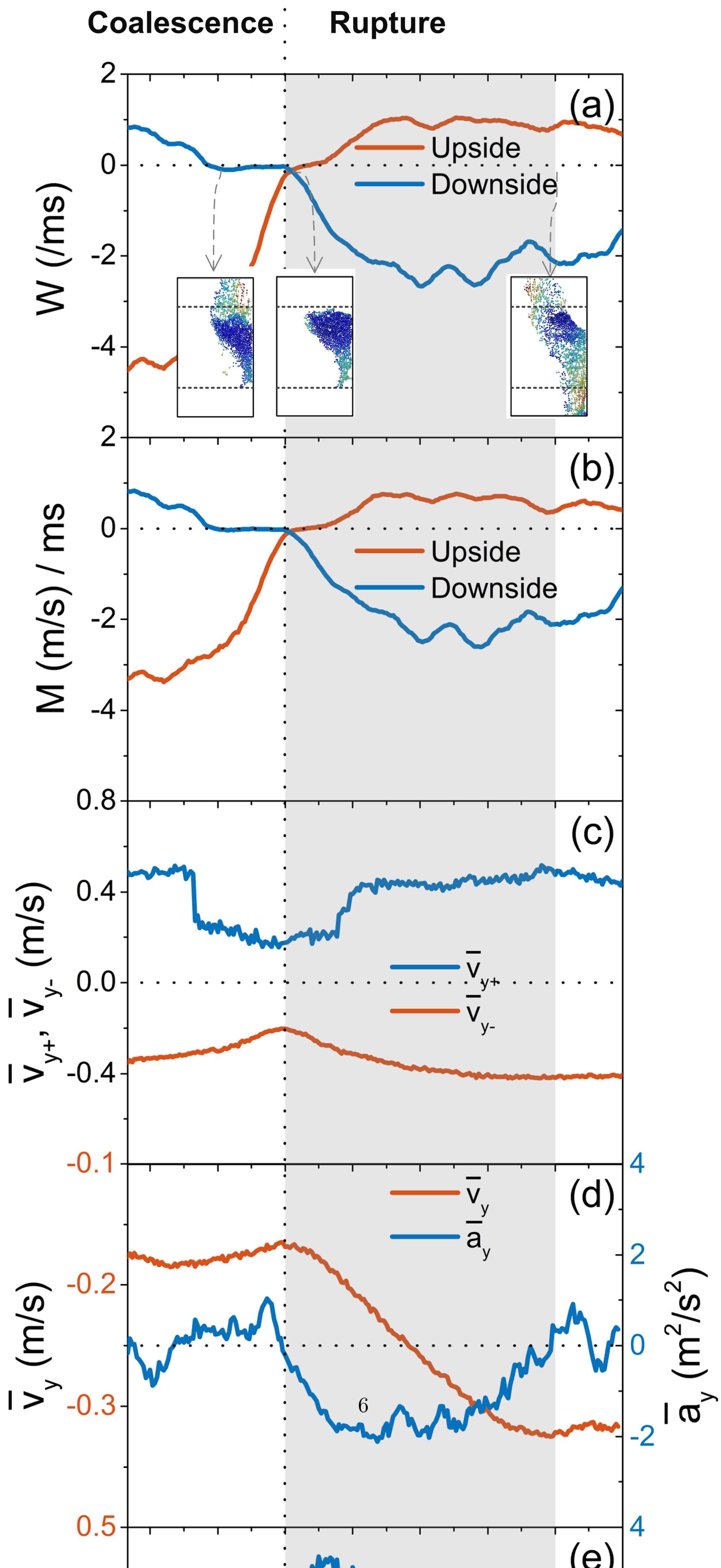

(a)
(b)
(c)
|v| m/s
1
0.8
0.6
0.4
0.2
0


(a)
All time
0-5s
5-10s
10-15s
$\sim n_c^{-2.2}$
Number Fraction
n_c
(b)
Middle
Wall
$\sim n_c^{-2.2}$
Number Fraction
n_c

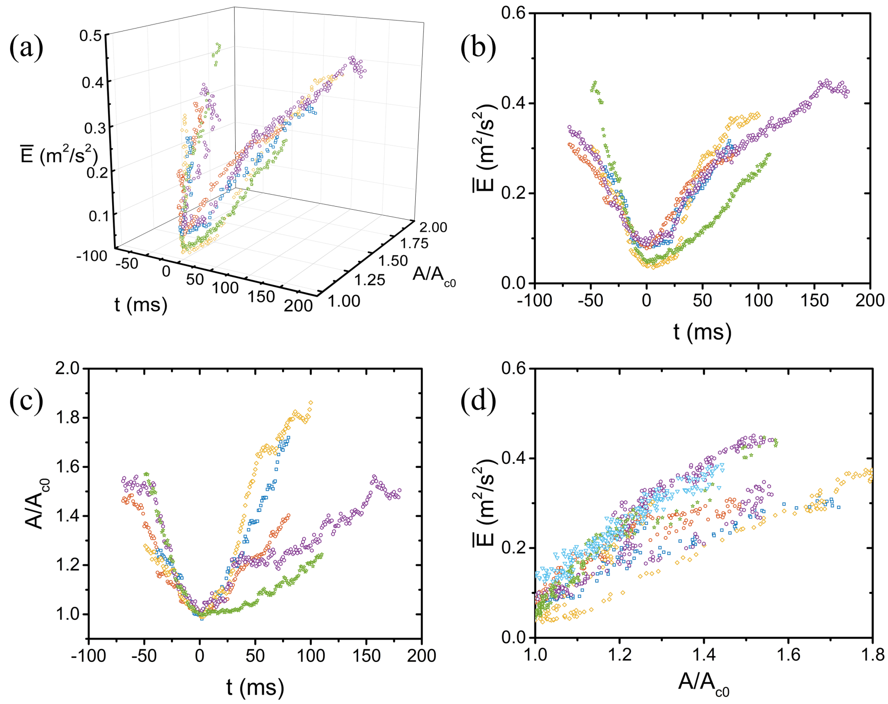

(a)
⟨U⟩ (m/s)
X (mm)
X_All
X_Big
Y_All
Y_Big
(b)
⟨Θ⟩ (m²/s²)
X (mm)

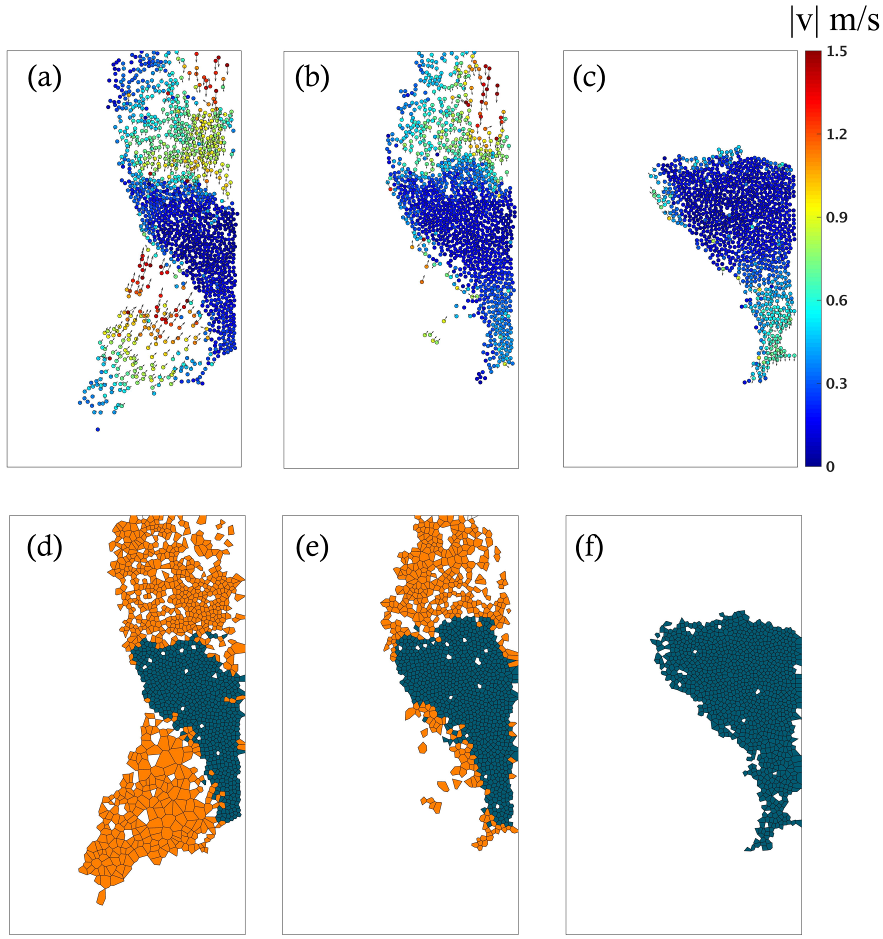

(a)
v_y m/s
(b)
a_y m/s²

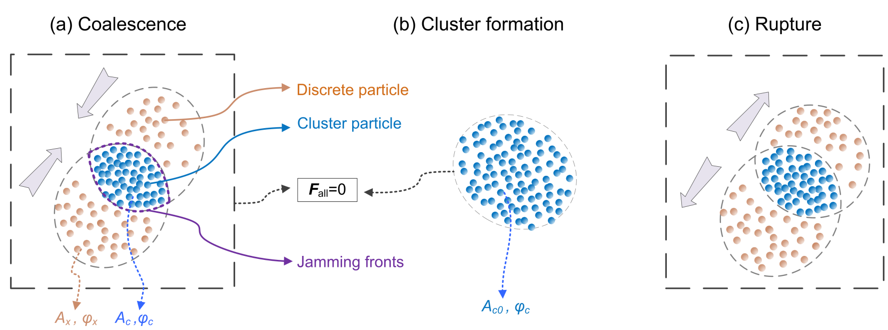

t=-70ms
t=-40ms
t=0ms
|v| m/s
1.5
1.2
0.9
0.6
0.3
0
t=40ms
t=80ms
t=120ms

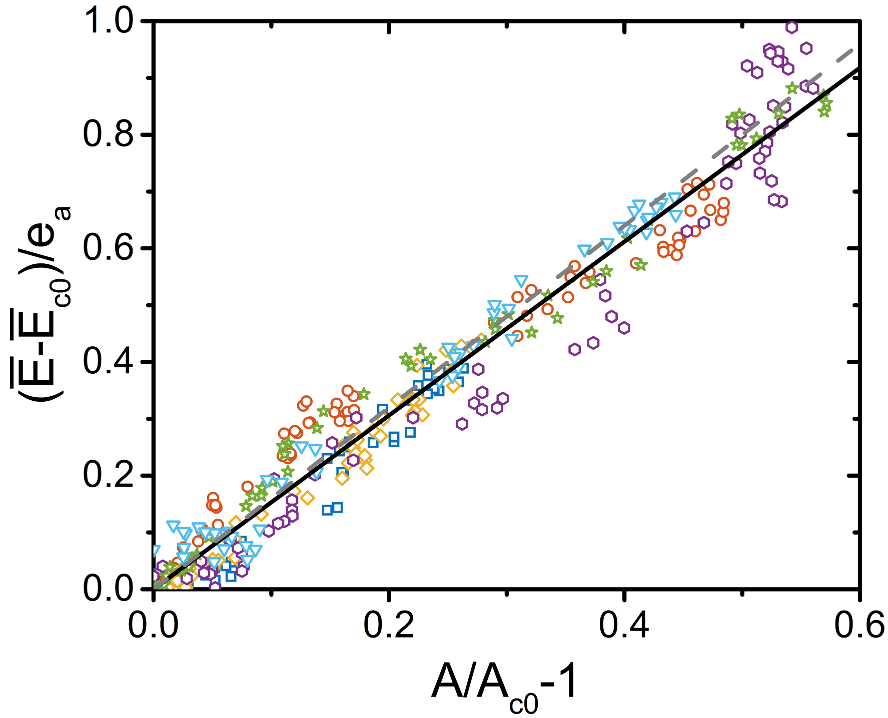


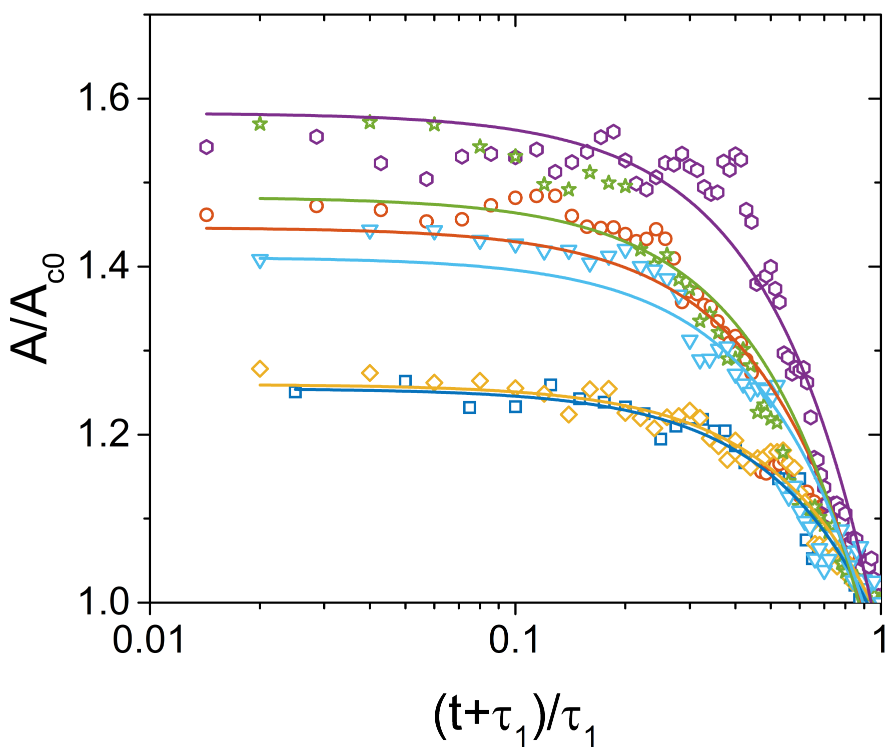
Coalescence
Rupture
(a)
Upside
Downside
W (/ms)
(b)
Upside
Downside
M (m/s) / ms
(c)
$\bar{v}_{y+}$
$\bar{v}_{y-}$
$\bar{v}_{y+}$, $\bar{v}_{y-}$ (m/s)
(d)
$\bar{v}_y$
$\bar{a}_y$
$\bar{v}_y$ (m/s)
$\bar{a}_y$ (m^2/s^2)
(e)

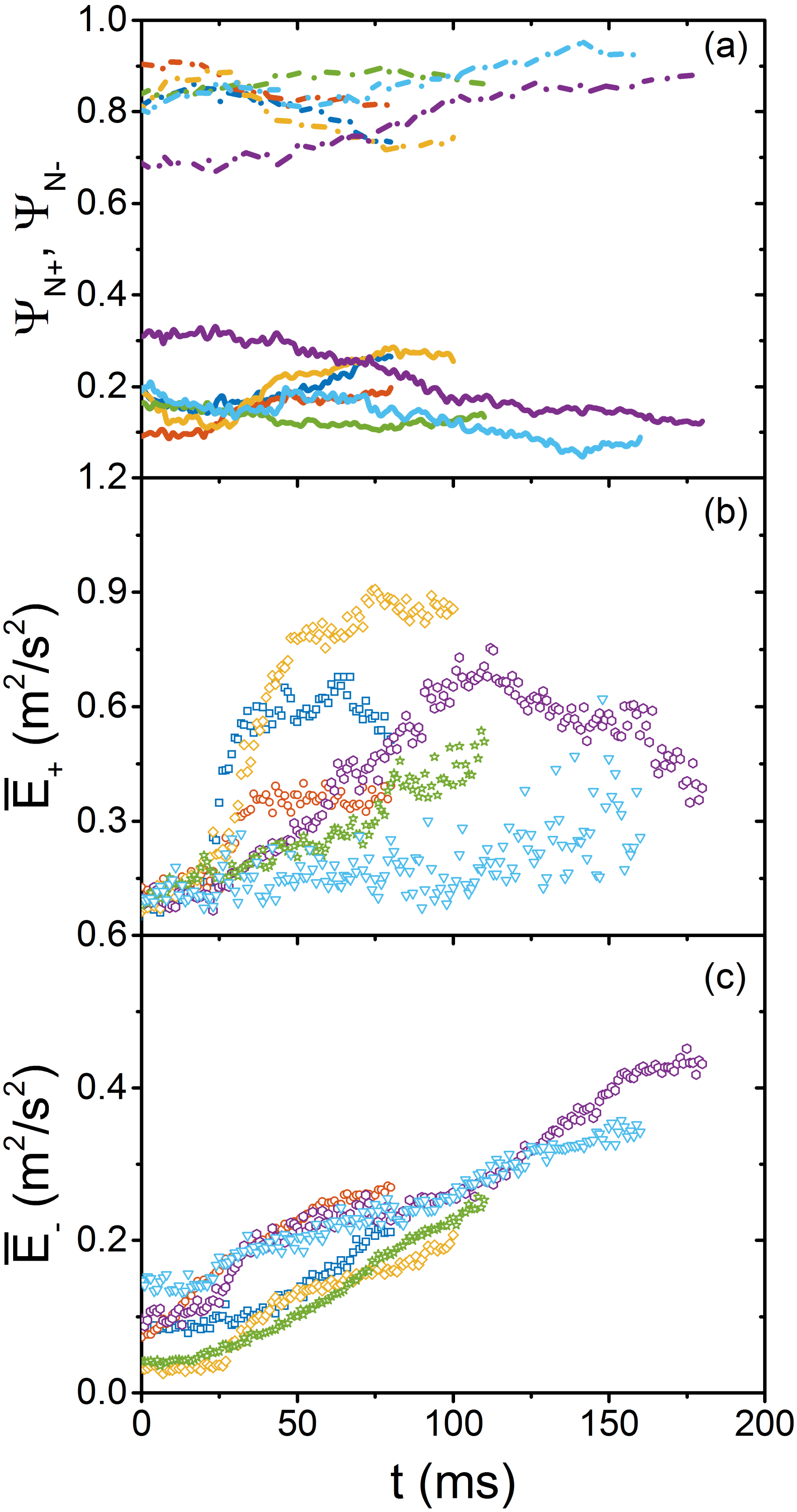

(a)
$\overline{E}$ (m^2/s^2)
t (ms)
A/A$_{c0}$
(b)
$\overline{E}$ (m^2/s^2)
t (ms)
(c)
A/A$_{c0}$
t (ms)
(d)
$\overline{E}$ (m^2/s^2)
A/A$_{c0}$

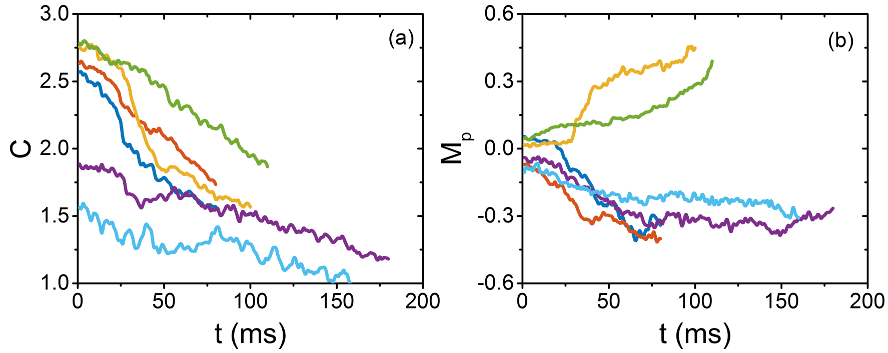

|v| m/s
1.5
1.2
0.9
0.6
0.3
0
(a)
(b)
(c)
(d)
(e)
(f)


(a) Coalescence
(b) Cluster formation
(c) Rupture
Discrete particle
Cluster particle
Jamming fronts
F_{all}=0
A_x, φ_x
A_c, φ_c
A_{c0}, φ_c


$(\overline{E}-\overline{E}_{c0})/e_a$
$A/A_{c0}-1$
0.0
0.2
0.4
0.6
0.8
1.0


A/A_{c0}
$(t+\tau_1)/\tau_1$
0.01
0.1
1
1.0
1.2
1.4
1.6


(a)
(b)
(c)
Ψ_{N+}, Ψ_{N-}
$\overline{E}_+$ (m^2/s^2)
$\overline{E}_-$ (m^2/s^2)
t (ms)
1.0
0.8
0.6
0.4
0.2
1.2
0.9
0.6
0.3
0.6
0.4
0.2
0.0
0
50
100
150
200


(a)
C
t (ms)
(b)
M_p
t (ms)