Summary of current literature concerning the shearing of foams.

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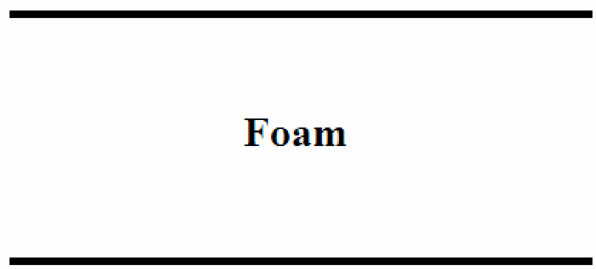
Here we present a summary, in the form of a table, of the literature concerning the shearing of foams. We would like to thank participants at the Grenoble Foam Mechanics Workshop, 2008 with particular acknowledement to Simon Cox and Michael Dennin for their contribution.

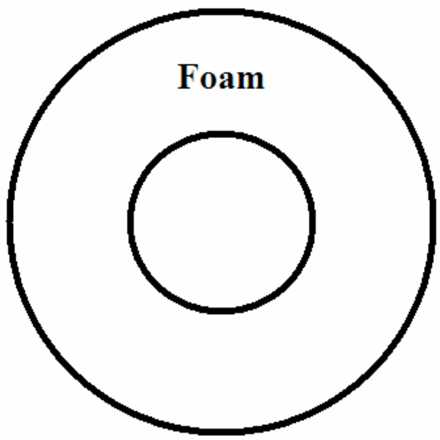
The motivations for compiling this list were to try and establish some common aspects amongst such a vast variation of parameters and geometries and to gain further insight into which factors lead to localization within a foam. For the purposes of this summary we define localization in terms of T1 events: A localized flow will have the majority of T1 events occurring within the same region of the foam.

We welcome any corrections or additions which should be sent to alw05@aber.ac.uk.

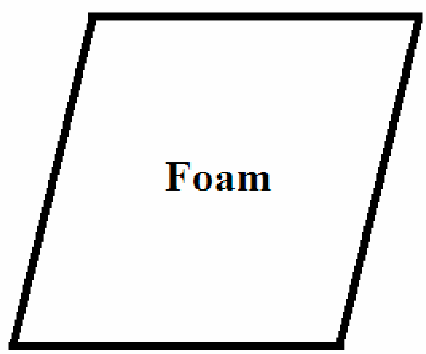
Linear Couette: Foam between two parallel bars (not to be confused with confining plates as with a Hele-Shaw cell) and one or both of the bars are moved.



Cylindrical Couette: Foam lies between two concentric cylinders and one of the cylinders is rotated.



Pure Shear: Foam lies between two pairs of parallel boundaries and one boundary is moved.



Author(s)	Year	S/E/T	2D/3D	Φ_l	Geometry	Polydispersity	Control parameters	Results/Data	Localization	Comments
LINEAR COUETTE										
Katgert Möbius van Hecke arXiv:cond-mat.soft/0711.4024 (2007)	2007	E	2D	?	• Linear Couette • Bubble Raft (Liquid-Glass) • No slip at moving boundaries. • Steady Shear: Move both boundaries in opposite directions • ~20-40 Bubbles between walls	Bidisperse	• shear rate • disorder • gap width	• **velocity profiles** • drag force per bubble induced by foam bubbles on glass plate as a function of capillary number	Y	
Wang Krishan Dennin prl 98	2007	E	2D	Wet	• Linear Couette • Bubble Raft • No slip at moving boundaries, ends open in horizontal direction. • Steady Shear: • Move both boundaries in opposite directions • ~21 bubbles between walls	Monodisperse		• probability distribution of velocities for ensemble averaging and time averaging for different positions in the trough • deviation of time average velocity profiles and ensemble average velocities from the mean profiles • correlation function vs strain • average deviation between different ensemble averages vs number of runs used to generate ensemble set	n/a	30 experiments. Comparison of time averaged data and ensemble averaged data.
Wang Krishan Dennin phil mag lett 87	2007	E	2D	Wet	• Linear Couette • Bubble Raft • No slip at moving boundaries, ends open in horizontal direction. • Steady Shear: • Move both boundaries in opposite directions • ~20 bubbles between walls	Monodisperse	• shear rate	• **T1 location for 2 different strain intervals** • **Probability distrubtion of orinetation of T1 events** • **# T1s vs time for different shear rates** • T1 rate vs shear rate	?	
Wang Krishan Dennin pre 74	2006	E	2D	Wet	• Linear Couette • Bubble Raft • No slip at moving boundaries, ends open in horizontal direction. • Steady Shear: • Move both boundaries in opposite directions • ~20 bubbles between walls	Relatively monodisperse' (Range of the volumes < 10% of the mean volume)	• strain rate	• Probability distribution of velocity components in different regions of the foam. • Spread of velocity distributions vs strain rate • Distributions of velocity fluctuations along the x and y directions • Location of peak in the distribution ov velocity fluctuation vs strain rate • Distn of displacement of bubbles • mean square displacement of bubbles vs time • diffusion constant vs shear rate • x and y displacement of a single bubble vs time	?	
Wang Krishan Dennin pre 73	2006	E	2D	Wet	• Linear Couette • Bubble Raft (with/without top plate) • No slip at moving boundaries, ends open in horizontal direction. • Move both boundaries in opposite directions • ~20 bubbles between walls	Monodisperse	shear rate	• **Velocity profiles with/without top boundary for different shear rates** • **T1 positions with/without boundary**	Y - With top N - Without	

Wyn Davies Cox epje	2008	S	2D	Dry <1%	• Linear Couette • SE:Quasistatic • No slip at walls. Periodic in direction of shear. • Steady Shear: • 1120 bubbles • ~20 bubbles between walls	Monodisperse & polydisperse	mu2(A)	• **T1 y position vs strain** • **x,y position of t1s** • position of localized region vs mu2(A) • width of localized region vs mu2(A) • **distribution of t1 orientations** • texture tensor, linear intercept method vs y	Y	
Kabla Debregeas jfm	2007	S	2D	dry 1%	• Linear Couette • Quasistatic • No slip at boundaries. Periodic in direction of shear. • Oscillatory Shear: move bottom boundary • 384 bubbles • 16 bubbles between walls	Slightly polydisperse	• strain amplitude	• stress,strain vs time for different strain amplitude • stress vs strain for different strain amplitude • energy dissipated per cycle vs strain amplitude • normal stress difference vs shear cycles/shear stress • normal stress difference under zero shear stress vs #cycles • energy vs strain for different strain amplitude • shear mod,structural energy vs # cycles for different strain amplitudes • **mu2(n) vs #cycles for different strain amplitudes** • **y pos of t1s vs # cycles** • shear mod vs # cycles	Y	
Kabla Scheibert Debregeas jfm	2007	S	2D	1%	• Linear Couette • Quasistatic • No slip at boundaries. Periodic in direction of shear. • Steady Shear: : move bottom boundary • 640 bubbles • 16 bubbles between walls	Slightly polydisperse		• shear stress, free energy vs strain • **y pos of T1 vs strain** • structural energy,shear mod, eps_plast,eps_elast vs strain • shear stress variation field, displacement field induced by a single t1 event • deformation profile induced by t1 event at wall and in middle • gradient of flow profile,frequency of t1 events vs distance from moving wall • distribution of energy released by avalanches • energy release v avalanche size • stress,strain fields for avalanches • x position of t1 vs t1 number • probability that two rearrangements separated by k-1 events in a sequence are located dx from each other • distribution of bubble shear stress deviation to local mean value (shear band,out band) • variance of static stress distn,structural energy vs strain	Y	
Cox Weaire Glazier rheol acta	2004	S	2D	Dry	• Linear Couette • SE:Quasistatic • No slip at walls. Periodic in direction of shear. • Steady Shear: • 750 bubbles	Monodisperse		• **t1 y position vs strain**	Y	

Kabla Debregeas prl90	2003	S	2D	dry ~1%	• Linear Couette • Quasistatic • No slip at boundaries. Periodic in direction of shear. • Steady Shear: move bottom boundary • 768 bubbles • 16 bubbles between walls	Slightly polydisperse		• **T1 y pos v wall displacement** • **T1 y pos histogram (trans/steady)** • **displacement profiles** • normal mean square displacement profile • displacement field associated with a single T1 event • variational shear stress field associated with a single T1 event • profile of shear stress variance	Y	
Jiang Swart Saxena Asipauskas Glazier pre 59	1999	S	2D	dry?	• Linear Couette • Oscillatory • Potts • No-Slip • Periodic in direction of shear. • # Bubbles?	mono/poly	• disorder • shear rate	• stored elastic energy v strain	?	
Jiang Swart Saxena Asipauskas Glazier pre 59	1999	S	2D	dry?	• Linear Couette • Potts • No-Slip • Periodic in direction of shear. • # Bubbles?	Monodisperse & polydisperse	• disorder • shear rate	• stored elastic energy vs time (boundary/bulk) (order/disorder) • **# T1 events vs time (boundary/bulk) (order/disorder)** • power spectra of #t1 events for different disorder and shear rate	Y	
Tewari Durian Knobler Langer Liu pre60	1999	S	2D	dry and wet	• Linear Couette • Bubble Model • No slip at walls. • Periodic in direction of shear. • 36 - 900 bubbles. • 6 to 30 bubbles across	polydisperse	• system size • shear rate • liquid fraction • type of dissipation in model	• energy, energy drop, # bubbles that change neighbours during an energy drop vs strain • energy drop size vs # bubbles that change neighbours during an energy drop • probablility distributions for energy drop rearrangement events and T1 events • fraction of bubbles involved in an energy drop vs duration of energy drops • distribution of energy drops for different system size, shear rate, type of dissipation and liquid fraction • distribution of # bubbles that change neighbours during a rearrangement for different system size, shear rate, type of dissipation and liquid fraction • event count of T1s and energy drops for different system size, shear rate, type of dissipation.	?	
Durian pre55	1997	S	2D	Wet	• Linear Couette • Bubble Model • No slip at walls. • Periodic in direction of shear. • ? Bubbles	Monodisperse & polydisperse	• polydispersity • liquid fraction • strain rate • system size	• avg,max stress vs strain rate • probability density for T1 releasing an energy dE for different system size	N?	Also Step strain (shear mod,pressure,co-ordination number, stress relaxation time vs liquid fraction for polydisperse & monodisperse shear mod vs co-ord no for poly,mono) and constant stress (stress/strain vs mod strain)

Durian prl 75	1995	S	2D	Wet	• Linear Couette • Bubble Model • No slip at walls. Periodic in directin of shear. • Simple shear: move top • 36 - 1024 bubbles. • 6 to 32 bubbles across	polydisperse	• system size • liquid fraction	• shear mod,pressure,co-ordination number, stress relaxation time vs liquid fraction • avg,max stress vs dimensionless strain rate	N?	
Janiaud Weaire Hutzler coll surf A	2006	T	2D	?	• Continuum • Linear Couette • No slip at boundaries, external dissipation. • Steady Shear: move boundary	n/a	• wall velocity	**• displacement, velocity profiles for different times** • strain, strain rate profiles for different times	Y	
Janiaud Weaire Hutzler prl 97	2006	T	2D	?	• Continuum • Linear Couette • No slip at boundaries, external dissipation. • Steady Shear: move boundary	n/a	• wall velocity	**• velocity profiles for different times** • strain rate magnitude,stress magnitude v total applied shear	Y	
Rouyer Cohen-Addad Vignes-Adler Höhler pre 67	2003	E	3D	dry ~1%	• Linear Couette • No slip	polydisperse	• strain rate • strain amplitude	**• velocity profiles for different strain intervals and strain rates** • yield strain v strain rate	Y?	gravity in opposing direction to shear
Rouyer Cohen-Addad Vignes-Adler Höhler pre 67	2003	E	3D	dry ~1%	• Linear Couette • No slip • Oscillatory	polydisperse	• strain rate • strain amplitude	• correlation factor (quantifies extent of irreversible structural changes) vs max strain	Y?	gravity in opposing direction to shear
Herzhaft j coll int	2002	E	3D	wet ~10 %	• Parallel plate • Slip or no slip • Steady shear: rotate boundary	polydisperse	• gap size • shear rate	• stress v time for different gap widths • shear rate v shear stress for different times • bubble sizes between plates for different times • bubble size distribution across rheometer gap as function of applied shear rate • slip velocity vs time	?	
Khan Schnepper Armstrong j rheol	1988	E	3D	wet and dry 3-8%	• Parallel plate • No slip • Oscillatory shear	polydisperse	• rotation rate • gas farction • frequency	• storage and loss moduli v frequency • torque,strain vs time	?	also stress relaxation technique (yield stress v shear rate)
Khan Schnepper Armstrong j rheol	1988	E	3D	wet and dry 3-8%	• Parallel plate • No slip • Steady shear	Polydisperse?	• ratation rate • gas farction	• viscosity vs shear rate and shear stress for different gas fraction • transient viscosity vs strain for different shear rates and gas fractions • shear modulus vs strain	?	

CYLINDRICAL COUETTE

Kabla Scheibert Debregeas jfm	2007	E	2D	1%	• Cylindrical Couette • Monolayer of bubbles between 2 glass plates • No slip at boundaries. • Steady Shear: : Move inner boundary • ? bubbles between walls	Polydisperse		**• velocity profiles for different rotation rates** **• velocity profiles for transient/steady** • distribution of bubble shear stress deviation to local mean value (shear band/out band) • static stress distribution,dynamic stress distribution for stationary regime for different distances from wall • variance of dynamic stress fluctuation vs delt/tau0,y	Y	
Katgert Möbius van Hecke arXiv:cond-mat.soft/0711.4024 (2007)	2007	E	2D	?	• Cylindrical Couette • Bubble Raft • No slip at moving boundaries. • Steady Shear • 5 Bubbles between walls	Bidisperse		• drag exerted by a 2d foam in a Taylor-Couette geometry as a funtion of capillary number	Y?	
Gilbreth Sullivan Dennin pre 74	2006	E	2D		• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Move outer boundary • 15-22 bubbles between walls	?	• outer radius • strain rate	**• velocity profiles for different shear rates** • critical radius v rotation rate for different system size • exponents obtained from fitting power law, herschel-bulkkley models vs rotation rate • critical rate of strain vs external rotation rate for diff system size • probability distribution for measuring critical radius • converngence of critical radius with time interval size	Y	
Dennin coll surf A 263	2005	E	2D	Wet ~5%	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ~20 bubbles between walls	Polydisperse	• strain rate	• velocity variance vs strain rate (flowing region/static region) • 2nd/3rd moments of velocity distribution v radial position (transient/steady) for different shear rates • velocity distributions at different radial positions • probability distribution of change in velocity	Y	
Twardos Dennin pre 71	2005	E	2D	wet	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ? bubbles between walls	Polydisperse	• effective rotation rate	• distribution of stress drops • avg stress drop vs effective rotation rate • stress drop for different rotation rates	Y?	
Twardos Dennin pre 71	2005	E	2D	wet	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Sequence of step strains: Move outer boundary • ~5-35 bubbles between walls	Polydisperse	• effective rotation rate • waiting time • system size	• stress v time • distribution of change in stress between one strain value and next • distribution of stress drops • average stress drop vs effective rotation rate • average stress drop vs system size for different waiting times	Y?	

Dennin pre 70	2004	E	2D	Wet ~5%	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ~15 bubbles between walls	Polydisperse		• stress v strain • **velocity profile** • bubble deviations from elastic flow (trans/steady) • #T1s v effective elastic modulus • **radial T1 position vs strain,** • **#T1s v strain** • **#T1s vs radial position,** • **velocity vs radial position** • **avg angular displacement of bubbs v radial position**	Y	
Lauridsen Chanan Dennin prl 93	2004	E	2D	~5%	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ? bubbles between walls	Polydisperse	• strain rate	• stress v time • **velocity profiles** • avg velocity during stress drops	Y	
Kabla Debregeas prl90	2003	E	2D	1%	• Cylindrical Couette • Glass-Glass • No slip at boundaries. • Steady Shear: • Move inner boundary • 20-25 bubbles between walls	Bidisperse		• **displacement profile** • normal mean square displacement profile • shear stress variance profile	Y	
Pratt Dennin pre 67	2003	E	2D	~5%	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ? bubbles between walls	?	• strain rate • system size	• stress v strain • probability distribution of stress drops for different strain rates • average size of stress drop vs strain rates • average stress v strain rate • average stress/strain rate vs strain rate • #stress drops per unit strain vs strain rate • fluctuation intensity vs strain rate for different system sizes • fluctuation intensity vs mean stress	?	
Lauridsen Twardos Dennin prl 89	2002	E	2D	10%	• Cylindrical Couette • Bubble Raft • No slip at boundaries. • Steady Shear: • Move outer boundary • ? bubbles between walls	Polydisperse	• strain rate	• **Velocity profile** • Stress v strain • Distribution of stress drops for different strain rates	Y	
Debregeas Tabuteau di Meglio prl 87	2001	E	2D	wet	• Cylindrical Couette • Glass-Glass • No slip at boundaries. • Steady Shear: • Move inner boundary • 20-25 bubbles between walls	Bidisperse		• **velocity profiles for differect liquid fractions** • spacial correlations of radial velocity	Y	
Dennin Knobler prl 78	1997	E	2D	wet	• Cylindrical Couette • Langmuir Monolayer • Steady Shear • slip?	Relatively monodisperse	• strain rate • liquid fraction	• velocity profile for the liquid-expanded phase • average # T1 events vs applied strain	N	

Cox pp cadair	2007	S	2D	Dry	• Cylindrical Couette • SE: Quasistatic • No slip at walls. • Steady Shear: move outer wall • 1/16th of a Couette cell periodic in theta direction. • ~300-~1100 bubbles	Bidisperse	• phi_l • system size	• shear stress v radial position for different LF • torsion v strain for different LF • steady state torsion v LF • proportion of iterations that result in drop in torsion v LF • avg drop size v LF • **radial position of T1s vs strain** • radial pos of T1s,t1 count v LF • radial position of T1s and T1 count vs #bubbles in foam • **displacement profiles for different LF (trans/steady)**	Y	
Cox coll surf A	2005	S	2D	dry	• Cylindrical Couette • SE: Viscous Froth and Quasistatic • No slip at walls. • 1/16th of a Couette cell periodic in theta direction.Steady Shear: move outer wall • 144 bubbles	Bidisperse	• shear-rate	• energy vs distance moved by outer wall for QS,VF • **radial position of T1 vs distance moved by outer wall**	Y	
Cox Weaire Glazier rheol acta	2004	S	2D	Dry	• Cylindrical Couette • SE: Quasistatic • No slip at walls. • Steady Shear: : move outer wall • 1/16th of a Couette cell periodic in theta direction. • 500 bubbles	Monodisperse		• **t1 y position vs strain**	Y	
Clancy Janiaud Weaire Hutzler epje 21	2006	T	2D	?	• Continuum • Cylindrical Couette • No slip at boundaries, external dissipation. • Steady Shear: • Move inner boundary or outer boundary	n/a	• wall velocity	INNER • **velocitry profile** • localization length vs inner radius • stress variation vs wall velocity OUTER • **velocity profile steady state for different regimes** • stress profiles for above regimes • stress variation vs wall velocity	Y	
Cheddadi Saramito	?	T	2D						Y	
Rodts Baudez Coussot europhys lett 69	2005	E	3D		• Cylindrcal Couette • No slip	Slightly polydisperse	• rotation velocity • applied stress	• **velocity profiles** • rotation velocity v time for differnet torque • torque v time for different velocity	Y	
Baudez Coussot prl 93	2004	E	3D	wet?	• Cylindrical Couette • Creep • No slip? • Move ? Boundary	Slightly polydisperse		• **rotation angle profiles for different times** • **rotation velocity profiles for different times**	Y	foam and gel
Baudez Coussot prl 93	2004	E	3D	~7%	• Cylindrical Couette • Torque oscillation • No slip? • Move ? Boundary	Slightly polydisperse	• torque amplitude	• phase angle profile for different applied torque amplitudes	Y	foam and gel

Bertola Bertrand Tabuteau Bonn j rheol	2003	E	3D	?	• Parallel disc • No slip or slip	?	• applied stress	• stress vs apparent shear rate for different gaps with and without rough plates	?	foam and emulsion
Bertola Bertrand Tabuteau Bonn j rheol	2003	E	3D	?	• Cylindrical couette • No slip • Steady shear: move inner boundary	Slightly polydisperse		**• velocity profile**	? Y (for emulsion)	foam and emulsion
Gopal Durian jcoll int	1999	E	3D	wet ~8%	• Cylindrical Couette • No slip • Simple shear: Move outer boundary	Polydisperse	• strain rate	• T1 correlations	Y?	
FULLY PERIODIC										
Vincent-Bonnieu Höhler Cohen-Addad europhyss lett 74	2006	S	2D	dry	• Fully Periodic • SE (variant) • Periodic in all directions. • Creep experiment • ? bubbles.	Polydisperse	• applied stress	• strain v time • compiance v time, • #T**1s v time** • variation of strain accompanying a t1 event • variation of strain between two successive t1s • probability distribution of time intervals between successive t1s for different constant applied stresses	Y	coarsening
Cox coll surf A	2005	S	2D	dry	• Fully Periodic. • No slip at walls. • Steady Shear: • SE: Viscous Froth & Quasistatic • 100 bubbles	Monodisperse	• strain rate	• energy v strain for different strain rates	Y	
Okuzono Kawasaki pre 51	1995	S	2D	dry	• Fully Periodic • Vertex model • Periodic in all directions. • Simple shear • ? bubbles.	Polydisperse	• shear rate	• energy density vs strain • stress v strain • velocity fields • displacement vectors of cells • probability density of avalanche size, stress jump in an avalanche • power spectra of time series of energy and shear stress	?	
Okuzono Kawasaki Nagai j.rheol	1993	S	2D	dry	• Fully Periodic • Vertex model • Periodic in all directions. • Simple shear • 459 bubbles.	Polydisperse	• strain rate	• stress, normal stress, density of interface rheology vs shear strai for diff strain rates • steady state shear stress vs shear rate **• T1 frequency vs strain,** • T1 frequency vs shear rate • interface energy density vs time	?	

Gardiner Dlugogorski Jameson jnnfm 92	2000	S	3D	wet	• Fully Periodic • Bubble model • Periodic in all directions. • Steady shear • 256 bubbles.	Polydisperse	• gas fraction • shear rate • polydispersity • bubble rearrangement times	• shear stress vs strain for different bubble distns and different bubble rearrangement timescales • normal stress differences for different bubb distns and bubb rearrangement times • excess surface energy per bubble v strain for different bubb distns • steady state shear stress vs shear rate for different liquid fractions • viscosity vs shear rate for different liquid fractions • dynamic yields stress, max stress vs gas fraction • # constacting bubble nieighbours and mu2(n) v shear rate	n/a	
PURE SHEAR										
Quilliet Idiart Dollet Berthier Yekini coll surf A 263	2005	E	2D	wet?	• Pure Shear. • Enclosed by 4 boundaries. • No slip in shear direction. • Liquid-Glass • Oscillatory shear • ? Bubbles	Monodisperse	• flaw/cavity area to bubble area ratio • maximum angle (strain amplitude)	• ditance of flaw from initial position vs #cycles for different flaw sizes • distribution of distance moved by flaw in one cycle • cavity relaxation parameter vs # shear cycles • cavity relaxation parameter vs #cycles with increasing strain amplitude	N	
el Kader Earnshaw	1999	E	2D	~3-7%	• Pure Shear. • Enclosed by 4 boundaries. • No slip in shear direction. • Oscillatory shear • 1500 Bubbles	Polydisperse		• distribution of # sides per bubble for strain = 0,0.75 • **mu2(n) vs strain** • reduction in mu2(n) from strain =0 to 0.75 vs initial mu2(n) • frequency distn of the size of the clusters of change	N	
Thomas Mombach Idiart Quilliet Graner coll surf A 263	2005	S	2D	?	• Pure Shear. • Potts • Enclosed by 4 boundaries. • No slip in shear direction? • Oscillatory shear • 400 Bubbles	Monodisperse	• flaw/cavity area to bubble area ratio • maximum angle (strain amplitude)	• cavity eccentricity vs mcs for different max angles and different cavityarea to bubble ara ratios • characteristic relaxation time vs cavity size • cavity centre of mass position for different cavity area to bubble area ratios • characteristic relaxation time vs max angle for different cavity sizes • centre of mass displacement vs time for different max angle • centre of mass displacement vs time for different cavity area to bubble area ratios	N	