

Index

Note: Page numbers in *italics* refers to figures.

a

abrasion 146
abrasive wear
 cavitation erosion 152–154, *152*
 liquid impingement
 erosion 147–148
 particle impingement erosion
 148–151, *149*
 synergetic cavitation-particle
 impingement erosion wear
 154–155, *155*
 theory and general findings 146,
 147
absolute pressure 28
acceleration 39–42
 along particle trajectories 61–63
 adjustable-gap valves 5
adsorption process 206
adverse pressure gradient 69
algae 254
amylopectin 269
amylose 269
antibiotics 18
axial centreline velocity in plane
 jet 75

b

backpressure 27–28, 113
Bernoulli equation 41, 109

biomolecules 18
biopolymer emulsifiers 201
Blake criterion 133
‘bleeding-hole’ techniques 116–117
bracing impact 159
breakup 182
 efficiency, effect on 138
Brinell hardness 148
bubble collapse 127–133
 zones 127

c

camera-microscope-laser 121
cascade breakup time 182
cavitating plume 125
cavitation 109, 259
 attempt to reconcile 191–192
 breakup visualisations 188–190,
 189, 191
 bubble collapse 127–133, *131*
 direct visual observations of
 cavitation 120–125
 drop breakup in presence of 187
 effect on breakup efficiency 138
 erosion 152–154, *152*
 extent 128
 in HPHs 116–120
 implications for industrial operation
 of HPHs 133–138

- cavitation (*Cont.*)
 - inception 135–137, 136
 - inception number 113
 - intensity 127–133, 131, 138
 - Kurzahls' argument 188, 188
 - location of cavitation in HPH
 - valve 125–127, 126
 - luminescence 123
 - pressure profile of streamline 110
 - regime and inception in simplified
 - valves 123–125, 124
 - regimes 137–138
 - shockwaves 112
 - Thoma number 112–116
 - wear 111, 111, 116, 156–158
 - cavitation-controlled emulsion drop
 - breakup 118
 - cavitation-induced ultrasonic
 - emissions 118–119
 - cavitation number 112–116
 - and operating conditions 133–135, 134
 - cell disruption 18–19, 19
 - cavitation 259
 - and cell structures in
 - HPHs 251–252
 - cells, cell structures and susceptibility
 - to homogenisation 252–255, 253
 - controlling mechanism 263
 - device optimisation 255–256
 - elongational strain in inlet
 - chamber 262
 - hydrostatic pressure 257
 - mechanism of 256, 257
 - physical impact 261–262
 - simple shear and gap
 - interaction 260
 - temperature 258
 - turbulence 258–259
 - cell structures 251–252, 253
 - cellulose 269
 - CFD. *see* computational fluid dynamics (CFD)
 - channel friction component 37
 - choked cavitation 125
 - CMC. *see* critical micelle concentration (CMC)
 - coalescence 210, 283–284
 - disperse phase volume fraction, effect
 - of 215–216
 - drop intermixing-based methods
 - 213, 213
 - emulsifier concentration, effect
 - of 215–216
 - homogenising pressure, effect
 - of 214
 - influence emulsification 199–200, 200
 - measuring during emulsification in
 - HPH valves 212–214
 - mechanism of 211
 - operating parameters, effect
 - of 214–216
 - PBM-based methods 212–213
 - perspectives on applicability 214
 - single drop-drop coalescence
 - 210–211, 210
 - coffee cream 13
 - collapse dynamics of small gas
 - bubble 129–130, 130
 - compression heating 33
 - computational fluid dynamics (CFD) 55
 - simulations 78
 - conservation of mass 30
 - controlling mechanism 263
 - corrosion 146
 - cream 13
 - critical micelle concentration (CMC) 125
 - cutting 149
- d**
- dairy high-pressure homogeniser 91
 - dairy processing 11
 - cream 13

ice cream 13–14
 milk homogenisation 11–13, 12
 yoghurt and fermented milk products 13
 deformation cracking 149
 destabilising stress 277
 device optimisation 255
 gap length 255
 impact distance 255–256
 dilatation 208
 dimensionless impingement length 82, 83
 direct numerical simulation (DNS) 76, 85–87, 185
 direct visual observations of
 cavitation 120
 cavitation regime and inception in simplified valves 123–125, 124
 cavitation region 123
 early investigations 121
 miscellaneous factors influencing transition 125
 state-of-the-art visualisation techniques 121–123, 122
 disperse phase modulation 67
 disperse phase viscosity, effect of 281–283
 disperse phase volume fraction, effect of 215–216
 dissipation rate of turbulent kinetic energy 73, 73, 84–92, 88, 89
 DNS. *see* direct numerical simulation (DNS)
 drop breakup mechanism
 gap 177–180
 high-speed drop breakup experiments 169–170
 inlet chamber–drop
 deformation 170–176
 outlet chamber 181–187
 in presence of cavitation 187–192
 drop deformation 170
 extent of 173–174, 173

observations 170–173, 170, 172
 production-scale HPHs, implication for 175–176
 quantifying 171–172
 visualisation experiments 174–175, 174
 drop diameter
 effect of flow rate on 227–228
 effect of homogenising pressure on 225–227, 226, 227
 from operating conditions to characteristic 225–231
 self-similarity plot for predicting 228–231, 229
 drop intermixing-based methods 213, 213
 drop radius 129
 drop relaxation 177
 dynamic forcer design 145

e

efficiency of pump 30
 elongation 63–64, 71–72
 rates 99
 elongational strain in inlet chamber 262
 empirical observations on HPH wear 155
 additional effects and remaining questions 158–159
 cavitation wear 156–158
 particle wear 156–158, 157
 emulsification 14, 202–203, 251
 general aspects 14–15
 in HPH valves 212–214
 linking performance to operation and valve design 223–224, 224
 nanoemulsions 16
 operating conditions to characteristic drop diameter 225–231
 optimal performance 231–236
 optimum valve design 238–240
 parenteral nutrition emulsions 15

emulsification (*Cont.*)
 scale-up of homogenisers for
 240–242
 thermodynamic efficiency of
 237–238
 emulsifiers 194
 adsorption kinetics 205–207, 205
 effect of emulsifier
 concentration 215–216
 influence emulsification 199–200,
 200
 interfacial rheology, turbulent drop
 breakup and 208–210, 209
 interfacial tension and surface
 load 202–205, 203, 204
 overview and classification
 200–202, 201
 emulsions 14
 Emulsor 8
 energy dissipation 131
 enzymatic lysis 18
 enzymes 269–270
 erosion 146
 rate 149–150
 wear predictions 161–162, 161
 extrusion 149

f

fermented milk products 13
 fixed-gap valves 5
 flow cavitation. *see* hydrodynamic
 cavitation
 flow pulsation 242
 flow rate
 effect on drop diameter 227–228
 hydrodynamic effect of varying
 48–50, 49
 flow regimes, implications for 34–36
 flow separation at seat wall 68–69,
 68, 69
 fluid compressibility 31
 fluid jet 75
 fluids 71
 forcer-position methods 36

free-radical formation 119–120,
 130–131
 freeze-thawing 18
 friction
 heating 33–34
 inlet chamber design
 influences 66–67
 fruit-based beverages 16–17

g

gap 29, 177
 breakup events 177
 drop breakup inside 177–178
 entrance angle 239
 exit angle 239–240, 240
 friction 37, 49
 implications for production-scale
 HPHs 179–180
 length 239, 255
 observations in 177, 177
 velocity 44
 gap height 34, 44
 experimental methods for
 measuring 36
 lift 120
 gap region 67–68, 67
 flow separation at seat wall 68–69,
 68, 69
 multiphase modulation 73
 turbulence and turbulent
 stresses 72–73
 velocity gradients, strain-rates, shear
 and elongation 71–72
 velocity profiles 69–71, 70
 gauge pressure 28
 gram-negative bacterial cells 253
 gums 268, 268

h

hardness and deformation resistance of
 materials 148
 heterogeneous nucleation 110
 high-pressure homogenisation 11, 15,
 17, 19–20, 269

- high-pressure homogenisers (HPHs)
 - 3–6, 27, 277
 - ability 3
 - cavitation in 116–120
 - components 28
 - disruption of cells and cell structures
 - in 251–252
 - empirical observations on HPH
 - wear 155–159
 - focus, ambition and relation to
 - previous work 6–7
 - high-pressure homogeniser-similar
 - valves 5
 - history 7–8
 - implications for industrial operation
 - of 133–138
 - location of cavitation in HPH
 - valve 125–127, 126
 - macromolecule break in 267–268
 - valve wear matters 145–146, 146
 - valves 29
- high-speed drop breakup
 - experiments 169–170
- high-temperature short-time (HTST) 12
- hold-up timescales 43, 44
- homogeneous nucleation 110
- homogenisation 16
 - cells, cell structures and susceptibility to 252–255, 253
 - microbial cells 252–254
 - vegetable and plant-based cell
 - structures 254–255
- homogenisers 6, 45
 - for emulsification applications,
 - scale-up of 240–242
- homogenising pressure 5, 14, 15, 17, 27–28, 28, 31, 44, 113
 - controller 145
 - effect of 214
 - drop diameter, effect on 225–227, 226, 227
 - hydrodynamic effect of varying
 - 47–48, 48
 - hot-spot theory 130–131
 - HPHs. *see* high-pressure homogenisers (HPHs)
 - HTST. *see* high-temperature short-time (HTST)
 - hydraulic diameter 34
 - hydrodynamic boiling. *see* hydrodynamic cavitation
 - hydrodynamic cavitation 110
 - hydrodynamic effect
 - of varying flow rate 48–50, 49
 - of varying homogenising pressure 47–48, 48
 - hydrodynamics 55, 56
 - hydrodynamic self-similarity 45
 - hydrostatic pressure 257

i

 - ice cream 13–14
 - impact angle 150, 150
 - impact distance 82, 255–256
 - impingement distance 82
 - indirect experimental methods 116
 - ‘bleeding-hole’ techniques 116–117
 - cavitation wear 116
 - free-radical formation 119–120
 - gap height lift 120
 - ultrasonic emissions 117–118, 117
 - industrial applications 11
 - industrially operated HPHs 145
 - initial breakup time 182
 - inlet chamber 29, 58, 170–176
 - design influences friction and
 - pressure losses 66–67
 - disperse phase modulation 67
 - elongational strain in 262
 - flow 58–61, 59, 60
 - friction losses 41
 - inlet geometry, effect of 65–66, 66
 - strain, elongation and shear 63–64
 - velocity and acceleration along particle trajectories 61–63
 - inlet friction loss coefficient 37, 38
 - inlet geometry, effect of 65–66, 66

interfacial rheology 208–210, 209
 interfacial tension 202–205, 203,
 204, 237
 inward radial flow valve 51–52, 51
 iodide release 119
 ionic group 201

j

jet-flapping 79
 jet formed at gap exit 74–77, 74,
 76, 77
 jet impingement 80–84, 81
 jet orientation 77–79, 78
 jet spreading 77

k

Kolmogorov–Hinze theory
 additional extensions 284
 disperse phase viscosity, effect
 of 281–283
 disruptive stresses 280
 insight from 277–280
 interpretation and main
 assumptions 285
 limited emulsifier concentration,
 effect of 283–284
 regimes or mechanisms of turbulent
 drop breakup 278
 turbulent viscous stress 280–281
 Kolmogorov length scale 271
 Kolmogorov timescale 92–93
 Kurzahls’ argument for cavitation
 controlled breakup 188, 188

l

laminar boundary layer 68
 laminar deformation 167
 large eddy simulation (LES) 85–87
 LES. *see* large eddy simulation (LES)
 limited emulsifier concentration, effect
 of 283–284
 liquid impingement erosion 147–148
 low static pressure effect 109
 low-viscosity emulsion 47

m

Mach number 31
 macromolecule disruption
 amylose, amylopectin, cellulose and
 derivatives 269
 break in high-pressure homogeniser
 valves 267–268
 empirical findings 268
 gums 268, 268
 mechanistic suggestions 270
 predictive models for 270
 proteins and enzymes 269–270
 strain-based model 272–273, 272
 turbulence-based model 271–272,
 271
 macroscopic strain 185–186, 185
 ‘macroscopic’ studies 154–155
 macroscopic view of flow in outlet
 chamber 79–80, 80
 ‘Marangoni stress’, 208
 mass continuity 29–30
 material erosion. *see* cavitation
 erosion
 maximum surviving drop
 diameter 278–279
 mean diameter 278–279
 mechanical technologies 18–19
 methyl cellulose 269
 microbial cells 252–254
 microfluidizer 5
 microjets 127
 ‘microscopic’ studies 154–155
 milk homogenisation 11–13,
 12, 18
 minor loss area-contraction
 component 37
 minor loss area expansion
 component 37
 minor loss friction coefficients 37
 momentum conservation 68
 multiphase modulation 73
 of outlet chamber
 hydrodynamics 100–101

n

nanoemulsions 16
 Navier–Stokes equations 60
 nectars 16
 needle valve 5
 net present value analysis
 (NPV) 233–234
 non-mechanical technologies 18–19
 nonthermal deactivation of
 microorganisms 19–20
 NPV. *see* net present value analysis
 (NPV)
 nucleation 110

o

Ohnesorge number 282
 older pressure correlation 37
 optimal performance 231
 cost-efficient valve size 233–236, 236
 energy efficient valve size 231–233,
 232–233
 optimum valve design 238
 optimising dimensions of traditional
 radial diffuser valve 239–240
 target and limitations in 238
 osmotic shock 18
 outlet chamber 29, 73, 181–187
 dissipation rate of turbulent kinetic
 energy in jet 84–92, 88, 89
 friction 37
 jet formed at gap exit 74–77, 74,
 76, 77
 jet impingement, stagnation pressure
 and wall shear 80–84
 jet orientation 77–79, 78
 macroscopic view of flow in 79–80,
 80
 multiphase modulation of outlet
 chamber hydrodynamics 100–101
 strain in outlet chamber 98–100, 99
 turbulent breakup in 183–186
 turbulent intermittency and outlet
 chamber jet 97–98

turbulent length scales and turbulent
 energy cascade 92–96
 overprocessing 16

p

parenteral nutrition emulsions 15
 partial homogenisation 12
 particle image velocimetry
 (PIV) 55–57
 particle impact on HPH valve
 159–161, 160
 particle impingement erosion
 148–151, 149
 particle trajectories
 velocity and acceleration
 along 61–63
 particle wear 156–158, 157
 PBM. *see* population balance modelling
 (PBM)
 PDFs. *see* probability density functions
 (PDFs)
 ‘pendant drop’ experiment 206
 Pickering emulsifiers. *see* Pickering
 particles
 Pickering particles 202
 PIV. *see* particle image velocimetry (PIV)
 plant-based beverages 17–18, 18
 plant-based cell structures 254–255
 ploughing 149
 population balance modelling
 (PBM) 212–213, 225
 potassium iodide 119
 power draw 30–31
 predictive models for macromolecular
 disruption 270–273
 strain-based model 272–273, 272
 turbulence-based model 271–272,
 271
 pressure 28
 pressure losses
 correlations 36–39, 39
 inlet chamber design
 influences 66–67

pressure profiles 39–42, 40
 primary valve 27
 probability density functions
 (PDFs) 98
 production-scale HPHs
 gap 179–180
 inlet chamber 175–176
 outlet chamber 187
 valves 32
 protein emulsifiers 202
 proteins 269–270

q

Q-criterion 96–97

r

radial diffuser valve 5
 RANS. *see* Reynolds-averaged
 Navier–Stokes (RANS)
 Rayleigh–Plesset equation 129
 Reynolds-averaged Navier–Stokes
 (RANS) 85–87
 Reynolds number 34–36, 48, 60,
 241–242
 Rockwell hardness 148

s

scalability, valve sizes 44–47
 scale parameter 133, 241–242
 scale-up of homogenisers 240
 flow pulsation 242
 scale parameter and Reynolds
 number 241–242
 seat impact angle 162
 secondary valve 27
 self-similarity 44
 self-similarity plot 63, 63, 90, 91
 for predicting drop diameter
 228–231, 229
 shear 63–64, 71–72, 72
 shockwaves 119
 similarity, valve sizes 44–47

single drop breakup visualisations
 181–183, 181–184
 single drop–drop coalescence 210–
 211, 210
 small turbulent eddies 185–186, 185
 solvent treatment 18
 stabilising resistance 277
 stacked valve designs 50–51, 50
 stagnation point 81
 stagnation pressure 80–84
 static pressure 28, 41–42
 Stokes correlation 162
 Stokes number 162
 strain 63–64
 strain-based model 272–273, 272
 strain in outlet chamber 98–100, 99
 strain-rates 71–72, 71
 strain-rate tensor 64
 strain-type flow parameter 63–64, 65
 stress balance 282
 super cavitation 124
 surface load 202–205, 204
 surface-weighted averaged drop
 diameter 279
 swaying 79
 synergetic cavitation-particle
 impingement erosion wear
 154–155, 155

t

Taylor length scale of HPH 95, 95
 temperature 258
 temperature rise 32–34, 32
 thermal pasteurisation 19
 thermodynamic efficiency of
 emulsification 237–238
 thermodynamic homogenisation
 efficiency 237
 Thoma number 28, 31, 112–116, 156
 tomato-based products 17
 total cost of ownership 233–234
 total pressure 28

- traditional radial diffuser valve
 - gap entrance angle 239
 - gap exit angle 239–240, 240
 - gap length 239
 - optimising dimensions of 239
 - transition zone 36
 - turbulence 72–73
 - turbulence-based model 271–272, 271
 - turbulence intensities 77
 - turbulent drop breakup 181, 208–210, 209
 - breakup modes and critical deformation 186, 186
 - macroscopic strain vs. small turbulent eddies 185–186, 185
 - production-scale HPH, implications for 187
 - single drop breakup visualisations 181–183, 181–184
 - turbulent breakup in outlet chamber 183–186
 - turbulent eddies 92, 96–97, 97
 - turbulent energy cascade 92–96, 93
 - turbulent flows 96
 - turbulent inertial breakup 279
 - turbulent inertial stress 277
 - turbulent intermittency 97–98, 98
 - turbulent jets 36, 75
 - turbulent kinetic energy 84
 - turbulent length scales 92–96, 94
 - turbulent stresses 72–73
 - turbulent viscous mechanism (TV) 278
 - turbulent viscous stress 280–281, 280
 - TV. *see* turbulent viscous mechanism (TV)
- U**
- UHT. *see* ultra-high temperature (UHT)
 - ultimate tensile strength 148
 - ultra-high pressures 34
 - ultra-high temperature (UHT) 12
 - ultrasonic emissions 117–118, 117
 - ultrasound 118
- V**
- valve flow-fields
 - challenges 102
 - gap region 67–73
 - inlet chamber 58–67
 - novel techniques 55–58
 - outlet chamber 73–101
 - valve geometry 29–30
 - valve hold-up times 42–44
 - valve sizes
 - similarity and scalability between 44–47, 46
 - valve varieties 50
 - inward radial flow valve 51–52, 51
 - stacked valve designs 50–51, 50
 - vapour-liquid interfaces 121
 - vegetable-based cell structures 254–255
 - velocity 39–42, 40
 - gradients 71–72
 - along particle trajectories 61–63, 61, 62
 - profiles 69–71, 70
 - vena contracta* effect 66–67, 126
 - Vicker hardness 148
 - violent collapse criterion 132–133
 - viscous friction 76
 - viscous stabilisation 282
 - volume-weighted averaged drop diameter 279
- W**
- wall shear 80–84
 - water molecules 202
 - wax-bead method 36
 - wear 145
 - abrasive wear, theory and general findings 146–155

- wear (*Cont.*)
 - applied perspective on remaining challenges 162–163
 - empirical observations on HPH wear 155–159
 - HPH valve wear matters 145–146, 146
 - insights on particle impact and particle erosion wear 159–162
- Weber number 183, 277
- Weisler reaction 119
- y**
- yield strength (Y) 148
- yoghurt 13

