а

agglomeration 5, 8, 24, 45, 52, 53, 70–76, 78, 83, 87, 104, 107, 115, 205, 300 atmospheric pressure 79, 87, 303, 314, 323

b

barometric leg 323 belt press 142, 275, 276 bond curve 266 bond number 265 *Bo* number 266, 269 "Boozer"-vacuum disc filter 119 bubble method 214 bubble-point measurement apparatus 313, 314 bubble point test 312, 313 Bucher press HPX5005 140 buoyant force 213

С

cake deliquoring cake moisture content 250 gas consumption 250 on hyperbaric drum filter 249 cake desaturation in centrifugal field cake moisture 262 capillary pressure curves 265 equilibrium 261–267 kinetics 267–268 piston-film model 267 in centrifuge beaker 262, 263 by gas pressure difference

capillary pressure curve for homogeneous filter cake 231 capillary pressure curve for inhomogeneous filter cake 232 deliguoring 235 desaturation matrix 240 equilibrium 231-234 gas flow through filter cakes 240 - 246kinetics 234-240 relative liquid and gas permeability 237,238 residual cake moisture 233 slurry concentration 233 by steam pressure filtration 257 function 258 principle 258 steam pressure with combined mechanical/thermal deliquoring 261 temperature profile 259 on vacuum drum filter 248 cake discharge 5, 43, 84, 107, 109, 110, 113, 120, 121, 141, 151, 154, 155, 157, 159, 185, 193, 276, 282, 300, 307-309, 323, 330 cake filtration process 1, 224 apparatuses 6, 92 application 3 basic principle 87 centrifuges design and operation 152-169 fundamental 146–152 compressible filter cake formation fundamental 123–130

Wet Cake Filtration: Fundamentals, Equipment, and Strategies, First Edition. Harald Anlauf. © 2019 Wiley-VCH Verlag GmbH & Co. KGaA. Published 2019 by Wiley-VCH Verlag GmbH & Co. KGaA. cake filtration process (contd.) optimization 133-136 parameters characterization 130 - 133effective driving pressure 87 equipment 7 incompressible filter cake formation filters design and operation 113-123 parameters characterization 98 - 104principle model 94–98 throughput of continuous vacuum and pressure filters 108-113 throughput of discontinuous cake filters 104-108 mechanisms 88 characteristic value 93 complex superposition 88 constant solids mass 90 deposition of particles 88 filter medium resistance 91, 93 flocculation 89 flotation coal 92 flotation coal slurry 89 Hermans and Bredée approach 94 linear representation 94 phase of bridge formation 88 pre-concentration 89 rotary filters 90 rotation speed 91 solids mass 89 special candle filter 92 principal modeling 88 steps 2,87 cake moisture, conversion of parameters 207 cake permeability 62, 65, 76, 94, 95, 97, 98, 107, 148, 149, 239 cake structure during formation process 41 ideal and real 61 incompressible and compressible 124 inhomogeneous 52 particle arrangement 49–52 pore size 52-54

porosity agglomerate 45 cubic and rhombohedral arrangement 46 elementary cell volume 47 function 48 irregular shaped 43 macro-pores 45 packing density 47 particle 44 pycnometric method 43 solidosity 44 typical values 43 van-der-Waals forces 48 void volume 42 zeta-potential 48 porous layers 41 principle 41 real geometry 41 cake washing 41, 87, 105, 138, 179, 180, 192, 196, 200, 204, 206 calendering process 308 capillary entry pressure 52, 68, 71, 84, 229, 230, 232, 233, 239, 247, 253, 259, 266, 278, 280, 282-286, 325, 326, 328 capillary flow porometry 41, 54, 312, 313 capillary force 35, 83, 114, 115, 122, 213, 235, 265, 266, 269, 280, 283 capillary method 214 capillary pressure 43, 71, 76, 83, 84, 200, 203, 205, 214, 222-231, 233-236, 239, 246-248, 254, 256, 258, 262-265, 270, 303, 313, 324, 325 capillary pressure curve 228–231, 234, 246-248, 264, 265, 279, 282, 285 capillary pressure distribution, for ZnS filter cakes 256 cellulose 4, 5, 15, 81, 82, 134, 302, 326 centrifugal desaturation 268 centrifugal filtration acceleration 146 applications 147 batch centrifuges 150 cake permeability 149

C-number 147 design and operation 152-169 geometrical parameters 149 light transmission profiles 148 pressure 146 principle 146 radiographic analysis 148 ceramic filter element, for disc filters 302 circular model pore 225 circular pore 312, 313, 315 co-current washing 177, 178 compressible cake structures 123, 128, 205 compressible filter cakes capillary pressure curve for 278 consolidation of average porosity 272 filter design and operation 274 - 278fundamental considerations 271 - 274mechanisms 273 porosity gradient 272 uniaxial pressing and shearing 271deliquoring by squeezing 205 by gas differential pressure cake porosity 285 cake shrinkage 285-288 consolidation/desaturation 278-285 deliquoring 282 drum filter with vibrating press belt 290 liquid bridge 281, 282 mechanical and thermal cake deliquoring 283 residual cake moisture 285 transferable tensile strength 280 vibration/squeezing 290 compression energy 243–245, 257 conductivity, of filtrate 181 conical disc filter cell 120 consolidation level (CL) 272, 273 continuous cake filtration process 106 continuous centrifugal cake filters 303

conventional microscopic analysis 312 counter-current washing 178, 192, 193 drum filter for 192 critical micelle concentration (cmc) 210 cross-flow filtration 183, 302, 329 Cubic structure 46

d

Darcy equation 60, 61, 93, 103, 124, 133, 237, 240, 242, 266 Darcy law 256 Debye length 74, 76 deliquoring process characterization 206-208 of compressible filter cakes by squeezing 205 density separation 3, 4, 176 desaturation 203 kinetics 203, 234, 235, 239, 249, 262, 267,328 desaturation, of filter cakes boundary surface 208 even and bent 222 between liquid and gas 208 surfactant migration 210 capillary pressure 222 circular model pore 225 deformation of boundary surface 223distribution 228 force balance for piece of boundary surface 222 pore channel of changing diameter 225 positive and negative 222 two-dimensional pore model 227 vapor pressure 224 contact angles 216 for dispersed particles 221 dynamic process 219 hysteresis effect 216 liquid bridges 218, 219 particles of interest on object plate 221 plate method 219, 220 press force on 220

desaturation, of filter cakes (contd.) for sharp edges and corners 218 non-wetting 216 soil-washing 216 surface tension 208 bubble method 214 capillary method 214 of different liquids 209 dynamic 212 as function of surfactant concentration 210, 211 plate method 213 ring method 212 of water 210 surfactants adsorption equilibrium 211 concentration gradient 211 migration 210 three-phase contact line 215 deformation of solid body 215 force balance 215 wetting definition 216 pore geometry 218 diafiltration, in fed batch mode 183 diaphragm filter press 275 heat transfer plate for 275 diatomaceous earth 4, 5, 15, 80–82, 302 dilution washing 176, 182 diafiltration in fed batch mode 183 in hydrocyclones 183 paddle washer 184 in single cake filtration apparatus 185 stirred pressure nutsche filter 186 two-stage co-current dilution washing 185 dimension matrix 58 disc filters, ceramic filter element for 302 discontinuous cake filtration process 106 dispersion 182, 186 in porous beds 187 displacement 80, 186–191, 214, 236, 237, 247, 258, 259, 283

dried harbor sludge, shrinkage cracks in 204 drum filter for counter-current washing 192 filtrate discharge 253 dutch weaves 304 maximal cut size 304 three-dimensional weave technology of 305

е

electrically enhanced press filtration 292–293 energy consumption, for mechanical and thermal cake deliquoring 246–248 extraction process 176

f

Fest pressure filter 201 FEST rotary pressure filter 178, 192 - 194fibrilized cellulose fibers 81 filter apparatuses 1, 6, 32, 41, 65, 76, 104, 105, 136, 178, 193, 201, 232, 251, 282, 299-301, 321, 323 filter cakes 176 fingering effects during permeation washing 188 gas consumption matrix 244 homogeneous 187 pore size distribution in 188 shrinkage cracks in 192 shrinkage of 198 filter cloth 92, 108, 110, 120, 123, 135, 137, 157, 159, 197, 199, 232, 309-312, 321, 322, 329 filter media belt filters 301 ceramic filter element for disc filters 302 depth 301 in double wire presses 301 drainage system 300 filter cake deliquoring 300 flow resistance 299, 310 function 299

interactions with slurry properties 299 particle retention 299 porometry 310-320 semipermeable 321-330 surface filtration 302 types 301 vacuum belt filter 302 woven filter media 304-310 filter press cycle 138 filtration kinetics, in filter presses 140 fingering effect 188, 227, 228, 236, 258 flocculation 45, 75, 80, 89, 196 flow resistance 4, 15, 50–54, 57, 68, 91, 97, 98, 120, 125, 127, 129, 130, 132-135, 151, 152, 156, 197, 299, 310, 312, 326, 327, 330 FrameTrak system 310 friction forces 60, 197

g

gas differential pressure, incompressible cake desaturation by 203 gas pressure 4, 41, 87, 100, 159, 201, 203, 219, 226, 231, 234–236, 243, 246, 261, 270, 278, 283, 314 Gibbs equation 208 glass beads 54, 62, 92, 221, 312, 313, 318 grade efficiency 28, 31

h

Hagen–Poiseuille equation 266 HiBar drum filter 111 HiBar oyster filter 112 homogeneous filter cakes 42, 52, 103, 139, 187, 231, 232, 243 horizontal filters 32, 115, 187 horizontal peeler centrifuges 153, 154, 157, 199 horizontal vacuum belt filters 192 hydrocyclone 4, 25, 26, 31, 66, 70, 76, 77, 164, 183 particle washing in 183 hydrostatic pressure 87, 119, 142, 146, 159, 214, 224, 314, 323 hyperbaric disc filter 110, 111 hyperbaric filter 110, 111, 192, 193, 201, 249

i

ideal sharp fractionation 27 incompressible cake desaturation, by gas differential pressure 203 influencing parameters 41, 58, 60, 94, 213, 239 integral material balance 26, 27 isentropic coefficient 243

k

Kaolin particles 15, 16 Kelvin-equation 224

I

lab filtration unit 98
laminar flow 30, 60, 66, 69, 127, 187
limestone filter cake, shrinkage cracks in 204
liquid bridges 203, 218, 219, 229, 237, 266, 280, 281
liquid flow through porous particle layers
dimension analytic approach 57–61
empirical approach 61–63
liquid properties 13, 14
liquid saturation degree 206, 228
liquid viscosity, permeation washing 188
lotus-effect 217

m

magnetic resonance imaging (MRI) 133, 258 matrix transformation 58, 59 maximal pore size 311, 317 microporous ceramic plates 321 microporous membranes 4, 5, 90, 91, 99, 226, 248, 299, 302, 305, 325–329 mode of filtration 96, 97 moving bed washer 190

n

non-wetting 218 definition 216

р

paddle washer 184 parallel cylindrical tubes 225 particle arrangement 41, 42, 46, 49–52 particle porosity 44 particle retention 299, 300, 304, 305, 310 particle washing characterization 180-182 co-current 178 counter-current 178 dilution 176, 182 limits 178-180 permeation 176, 186 principles 176-178 particles collectives characterization 20-24 fractionation 24-31 properties 14-31 single, of characterization 16–19 peeler centrifuges 10, 151, 153–159, 199, 267, 269, 270, 289 permeation washing 176, 181 dispersion in porous beds 187 drum filter for counter-current washing 192 FEST rotary pressure filter 193 on filter presses 196 fingering effect 188 in horizontal peeler centrifuges 199 on lab scale diaphragm filter press 194 liquid viscosity on 188 moving bed washer 190 pusher centrifuges 194 shrinkage cracks in filter cake 192 shrinkage of filter cakes 198 stagnant locations near filter media 197 steam cabin 200 steam pressure filtration 201 steam washing and deliquoring 200 vacuum belt filter 192 vacuum pan filter 193 in ventrical filter centrifuges 196 washing time, influence of 189

wash ratio, influence of 189 piston-film model 267 plate method contact angles 219, 220 surface tension 213 poreless membranes 4 pore size 52, 54 determination capillary flow porometry 313 conventional microscopic analysis 312 direct measuring methods 312, 313 glass beads 313 indirect measuring methods 312, 313 distribution 311 porometry bubble-point and microscopic analysis circular pore 316 slotted pore 317 square shaped pore 318 bubble-point and sieving analysis dutch weaved fabrics 320 lace weaved fabrics 320 bubble-point correlation 315-318 bubble-point measurement apparatus 313 circular pore 315 maximal pore size 311 pore size determination 312-315 pore size distribution, wet and dry run 314 single plain dutch weave pore 318 slotted pore 317 square shaped pore 316 triangular shaped pore 317 porosimetry 41 porosity agglomerate 45 for different pressure 136 elementary cell volume 47 function 48, 51 irregular shaped 43 macro-pores 45 packing density 47

particle 44 pycnometric method 43 solidosity 44 typical values 43 van-der-Waals forces 48 void volume 42 zeta-potential 48 press force, on contact angles 220 press nips 143, 276, 277 press rollers 276 cake shearing 277 pressure candle filter 113, 114 pressure filter cell 98–101, 109, 124, 130-132, 233, 246, 247, 249, 265, 285, 286, 322, 325 PTFE membranes 325, 326 pusher centrifuges 8, 14, 65, 160–162, 164, 165, 167, 194, 269

r

real technical fractionation 27 relative gas permeability 237, 242, 243 residual cake moisture 46, 69, 77, 135, 144, 175, 207, 233, 246, 252, 254, 255, 257, 269, 279, 282 Reynolds-number 59 rhombohedral structure 46 ring method 212 Rosin–Rammler–Sperling–Bennet (RRSB) 230 rotary filters, throughput and cake moisture of 251–257

S

scraper discharge 5, 324 screw press 134, 143, 144, 275, 277 sedimentation analysis 17, 312 semipermeable filter media cake deliquoring on membranes and fabrics 328 cake formation on membranes and fabrics 327 continuous filtration cake formation for 329 cake moisture content for 329 gasless filtration on vacuum drum filters

barometric leg 323 hydrophobic PTFE-membrane 325 installation 322 process 323 membrane bubble point 326 vacuum disc filter with microporous ceramic filter media 321 shrinkage cracks 243 in a dried harbor sludge and limestone filter cake 204 in filter cake 192, 286 prevention by cake pre-consolidation 289 shrinkage, of filter cakes 198 slotted pore 317 slurry agglomeration bridging 74 cake filtration process 71 capillary pressure distribution 71 coagulation 71 electrically charged particles 72 electrostatic repulsion energy 73 hydroxyl group formation 72 natural polysaccharides 74 negatively charged particle 72 particle size distribution 71 polar water molecules 72 pre-built bridges 71 precondition 71 single small particles 70 water-soluble macromolecules 74 Zeta-potential 73 chemical conditioning 83-84 composition and properties 13 filter aids-body feed filtration 80 - 82fractionation 75-80 liquid properties 14 particle properties collectives, of characterization 20 - 24general aspects 14-16 single, of characterization 16-19 pre-treatment 65 sampling 35-38

slurry (contd.) solids concentration 32-33 stability 33-35 thermal conditioning 83 thickening characteristic parameter 69 drag coefficient 67 economical 66 force of gravity 67 hydrocyclone 66 sedimentation processes 70 single particle sedimentation and segregation 66, 68 solids concentration 68 Stokes law 67 slurry pre-thickening 252 soil-washing 216, 217 solid liquid separation physical principles 3 processes 5,8 solidosity 43, 44 solids concentration 32, 33 sphericity 18, 19 square shaped pore 90, 316, 318, 319 squeezing, deliquoring of compressible filter cakes 205 staple fibers 307, 308 steam cabin 200, 258 steam generator 261 steam pressure filtration 201 cake desaturation by 257 stirred pressure nutsche filter 68, 115, 116, 185, 186 stochastic homogeneity 42 Stokes law 66, 67 sub-surface 211 surface filters 302 surface filtration 4, 301, 302 surface tension 203 desaturation, of filter cakes 208 - 270surfactants, migration 210

t

tensile strength 204, 278, 280, 282, 283, 286, 306 threads 120, 122, 304–308, 318 three-dimensional shrinkage, of homogeneous cakes 287 tower filter press PF 180 139 triangular shaped pore 317 tube diaphragm press 140 tubular pore model 53 two-dimensional pore model 227 two-dimensional shrinkage of cakes with a porosity gradient 288 of homogeneous cakes 287 two-stage co-current dilution washing two-stage co-current dilution washing, by vacuum drum filters 185

u

ultra-filtration membranes 302

V

vacuum belt filters 108, 117, 178, 192, 290.302 vacuum disc filter, with microporous ceramic filter media 321 vacuum drum filters 82, 109 two-stage co-current dilution washing 185 vacuum pan filters 76, 116, 178, 193, 195, 200, 257 vacuum rotary filters 179 van-der-Waals attractive forces 313 van-der-Waals forces 114, 205 vapor pressure 110, 159, 175, 224, 270, 303 ventrical filter centrifuges 196 vibrating press belt 290

W

wash liquid 46, 175, 176, 178, 179, 181–193, 196–201, 204, 286 Wenzel-equation 217 wettability 77, 216, 217, 308 wetting 218 capillary 214 definition 216 woven filter media calendering process 308 double weave structure 305 dutch weave 304

exchangeable drum filter cells 310 filter bag on disc filter segment 309 FrameTrak system 310 plain weave pattern 306 thermal and chemical stability of polymers 307 thread structures 307 three-dimensional weave structure 305 weave structures 304 WRING-press 141, 142

у

Young-equation 215, 217 Young-Laplace equation 222, 228, 313, 326

Ζ

Zeta-potential 34, 35, 48, 72, 73, 87