

Contents

1	Introduction.....	1
2	State of the art.....	4
2.1	Methods of centrifugation and washing.....	4
2.2	Centrifugal washing.....	8
2.3	Scope of this work and its differentiation from existing works.....	10
3	Fundamentals of particle technology and solid/liquid separation.....	12
3.1	Characterization of dispersed systems.....	12
3.1.1	Single particle characterization.....	12
3.1.2	Characterization of filter cakes.....	15
3.1.3	Characterization of liquid solutions.....	15
3.1.4	Adsorption theories.....	17
3.2	Solid/liquid-separation.....	18
3.2.1	Cake formation and permeation.....	18
3.2.2	Cake deliquoring.....	20
3.3	Characterization of washing processes.....	24
3.4	Models of cake washing.....	28
3.4.1	Residence Time Distribution (RTD) models.....	28
3.4.2	The equilibrium sorption model.....	35
4	Materials for the investigations.....	37
4.1	Solid particles.....	37
4.1.1	Class F-0.....	37
4.1.2	Class F-1.....	39
4.1.3	Class F-2.....	41
4.1.4	Class F-3.....	42
4.2	Mother liquor.....	45
4.3	Impurities.....	45
4.4	Wash media.....	45
5	Technical tools and experimental apparatuses.....	46
5.1	Experimental apparatuses.....	46
5.1.1	Earth Gravity Column (EGC).....	46
5.1.2	Centrifuges.....	48
5.2	Offline instrumentations and analytics.....	54
5.2.1	Conductivity Measurement.....	55
5.2.2	Ion Selective Electrodes.....	55
5.2.3	Atomic Force Microscopy.....	56
5.2.4	Further analytical methods.....	56
5.3	Experimental procedures.....	56
5.3.1	Sorption measurements.....	57
5.3.2	Preparation of the suspensions.....	58

5.3.3	Deliquoring and washing experiments	58
5.3.4	Post-treatments	60
6	The role of initial process conditions in cake washing	61
6.1	Influence of the liquid distribution on the cake surface	61
6.1.1	Industrial significance and technical problems	61
6.1.2	Experimental results	62
6.2	Influence of the pre-deliquoring time	65
6.2.1	Industrial significance and technical problems	65
6.2.2	Experimental results	65
6.3	Influence of the initial cake saturation	69
6.4	Different behaviors of products with various properties	73
6.4.1	Washing particles of different sizes	73
6.4.2	Washing particles with microscopic surface roughness	75
6.4.3	Washing particles with distinct surface roughness	82
6.4.4	Washing particles with poor wetting behavior	84
6.5	Conclusions to the role of initial saturation on filter cake washing	87
7	The role of process parameters during cake washing	89
7.1	Industrial significance and technical problems	89
7.2	Influence of the wash liquor flux	90
7.3	Dynamics of Washing and Deliquoring	94
7.3.1	Concept of the Flow Ratio (FR)	94
7.3.2	Concept of the dynamic saturation	97
7.3.3	Analyses of the washing kinetics	100
7.3.4	Influence of the maximum wash saturation	102
7.4	Influence of the cake thickness	107
7.5	Influence of the g-factor and the Bond regimes	110
7.6	Further considerations on wash liquor maldistribution in a filter cake	113
7.7	Conclusions to the role of process parameters during cake washing	116
8	Theoretical aspects of deliquoring and washing	118
8.1	Calculation of the saturation progression	118
8.2	The dispersion model	123
8.3	The mixing-cell model	129
9	The role of solubility and porous solids structure in cake washing	136
9.1	Industrial significance and technical problems	136
9.2	Handling soluble materials	137
9.3	Handling mesoporous materials	145
10	Technical realizations, future prospects and innovations	151
10.1	Demands on product formulation	151
10.2	Demands on apparatus design	152
10.3	Novel methods of purification	153
10.3.1	Particle relative motion	153
10.3.2	Pulsed wash liquor addition and multistage washing	154

10.3.3	Washing multiphase impurities	155
10.3.4	Washing compressible cakes	156
10.3.5	Removal of aqueous mother liquor by oil	157
10.3.6	Washing with additives	157
10.3.7	Alternating electric field combined with convective flow for washing mesoporous particles	158
10.3.8	Marangoni microconvection in washing with liquid containing dissolved gas	159
11	Conclusions	160
11.1	Technical apparatus.....	160
11.2	Initial conditions before washing.....	161
11.3	Process conditions during washing.....	161
11.4	Theoretical description of washing and deliquoring.....	162
11.5	The role of solids solubility and inner porous structure.....	163
11.6	Recommendations and future prospects.....	165
	References	166
	Nomenclature	178
	Appendix	183