UCM INGENIERÍA QUÍMICA

WET END OPTIMIZATION

A. Blanco and C. Negro
Complutense University of Madrid

ablanco@ucm.es
cnegro@ucm.es

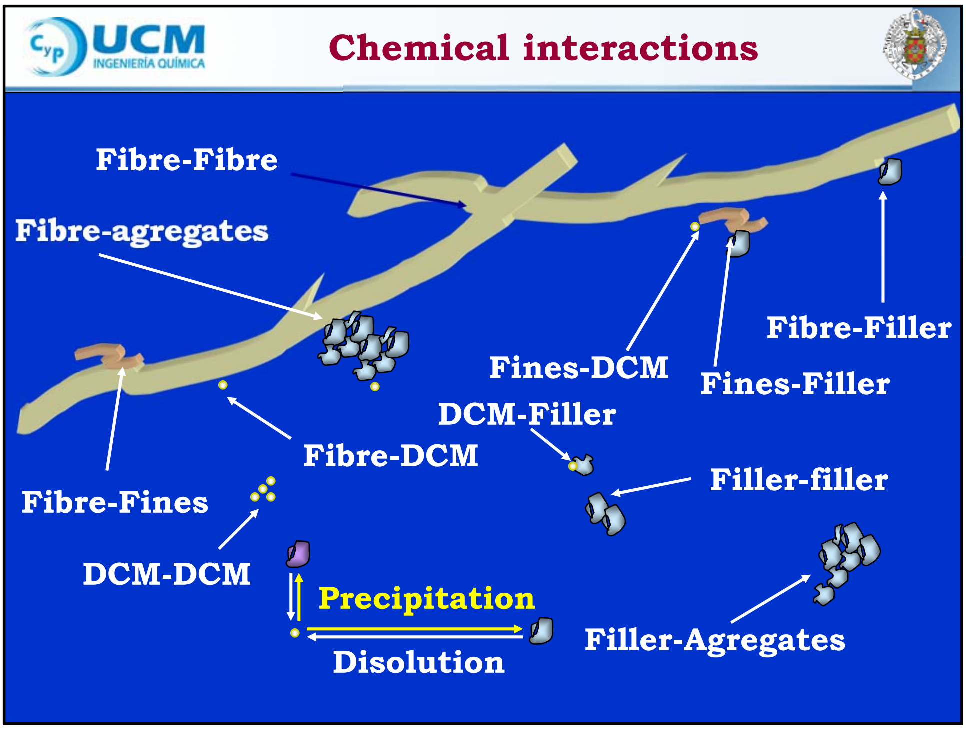
UCM INGENIERÍA QUÍMICA

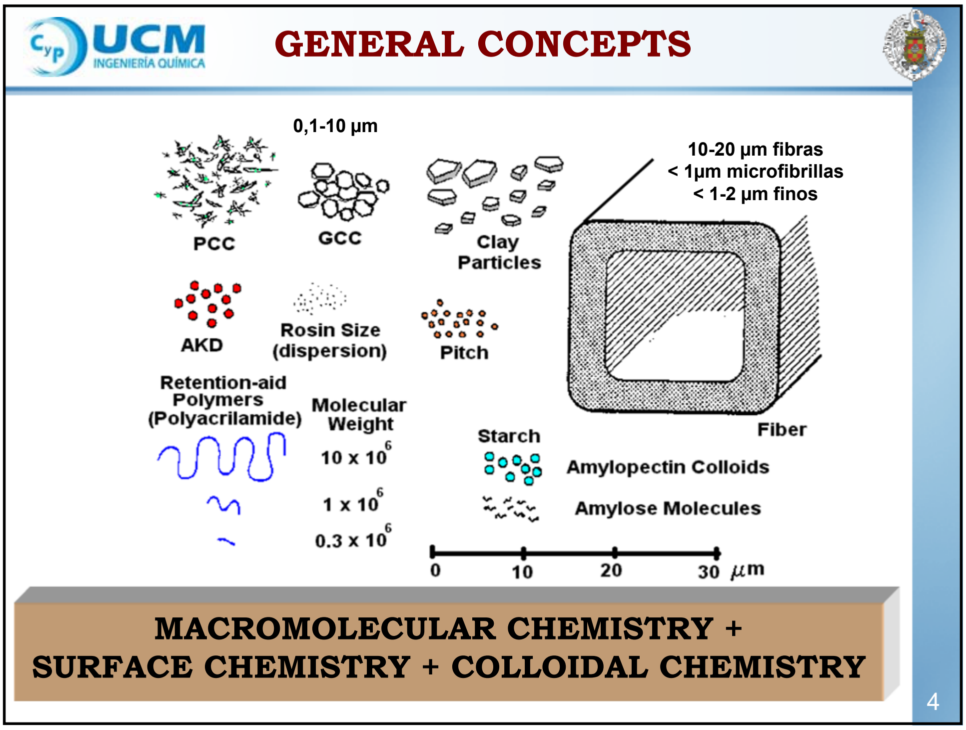
Content

- How to improve the effectiveness of papermaking chemicals.
- Balance between retention and drainage.
- Integration of water and retention system management
- On-line wet end control.
- Wet-end audit: Case studies.

Monash, 16th August 2018

2


UCM
INGENIERÍA QUÍMICA
Chemical interactions
Fibre-Fibre
Fibre-agregates
Fibre-Filler
Fines-DCM
Fines-Filler
DCM-Filler
Fibre-DCM
Filler-filler
Fibre-Fines
DCM-DCM
Precipitation
Filler-Agregates
Disolution


UCM
INGENIERÍA QUÍMICA
GENERAL CONCEPTS
0,1-10 µm
PCC
GCC
Clay Particles
10-20 µm fibras
< 1µm microfibrillas
< 1-2 µm finos
AKD
Rosin Size (dispersion)
Pitch
Retention-aid Polymers (Polyacrilamide)
Molecular Weight
10 x 10^6
1 x 10^6
0.3 x 10^6
Starch
Fiber
Amylopectin Colloids
Amylose Molecules
0
10
20
30 µm
MACROMOLECULAR CHEMISTRY +
SURFACE CHEMISTRY + COLLOIDAL CHEMISTRY
4

PAPERMAKING CHEMISTRY

- **When colloids are in a polar medium, they develop a surface charge:**
  - **Repulsion of particles**
  - **Attraction of counter-ions**
- **This, in addition to their tendency to mix due to thermal movements accounts for the formation of the electrostatic double layer.**

ash, 16th August 2018

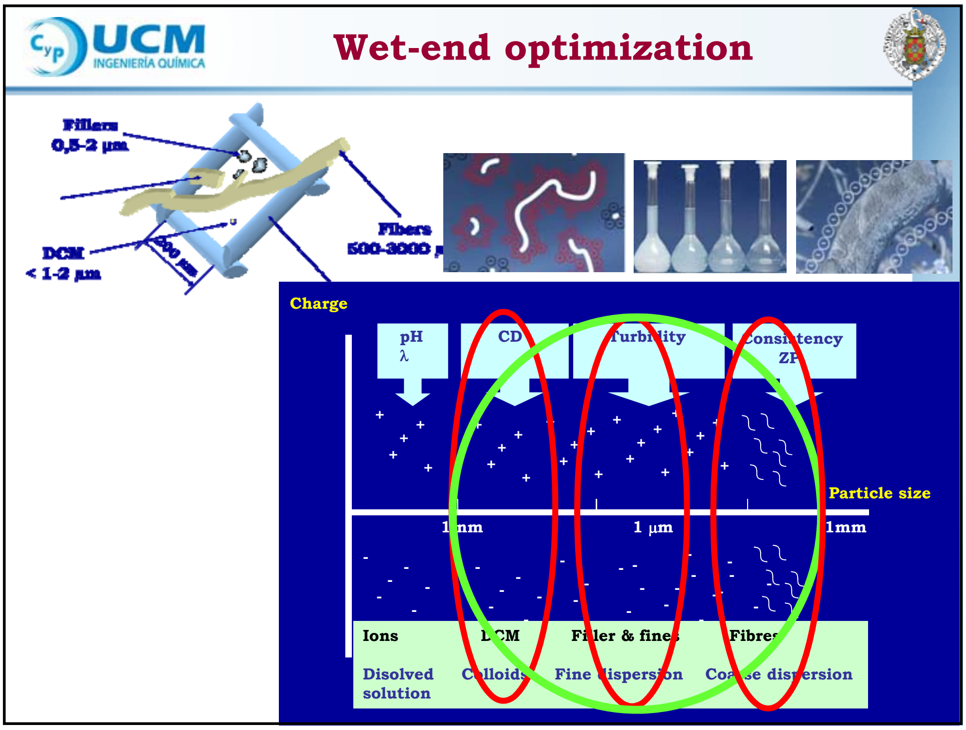
6

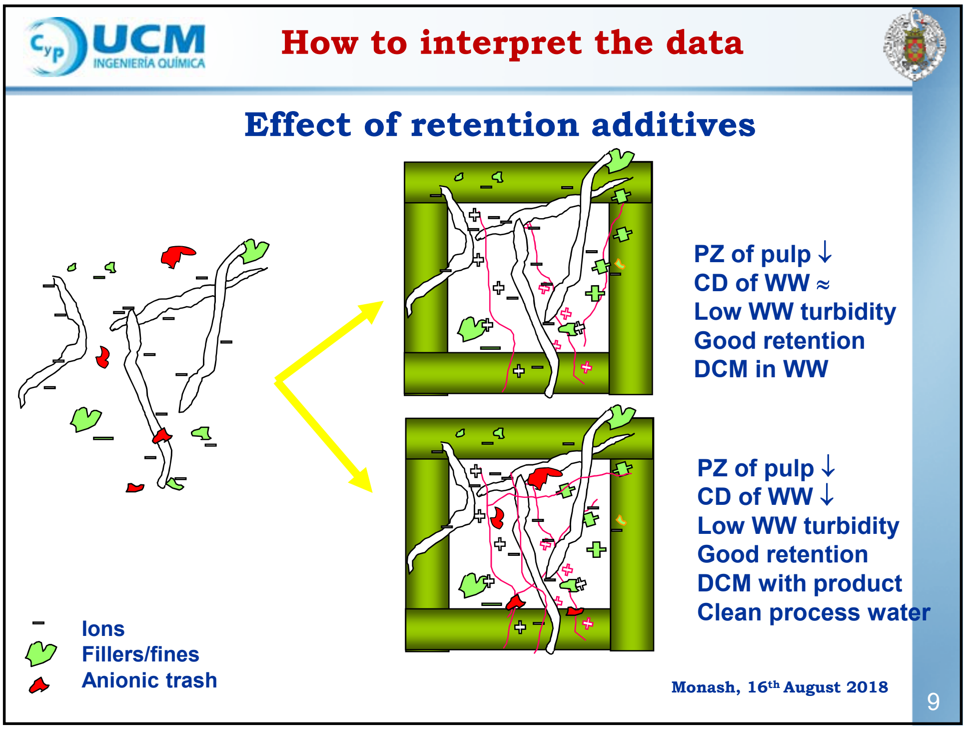
Electrokinetic theory

- **It is based on the electrostatic double layer and stream flow theories.**
- **There is an important relation between the ZP and the stability of colloids.**
- **There is a correlation between ZP and electrokinetic parameters.**
- **If one of the phases moves tangentially in respect to the other, electrokinetic effects can be observed.**

Monash, 16th August 2018

7


UCM
INGENIERÍA QUÍMICA
Wet-end optimization
Fillers
0,5-2 µm
DCM
< 1-2 µm
Fibers
Charge
pH
λ
CD
Turbidity
Consistency
ZP
Particle size
1 nm
1 µm
1mm
Ions
DCM
Filler & fines
Fibres
Disolved solution
Colloids
Fine dispersion
Coarse dispersion

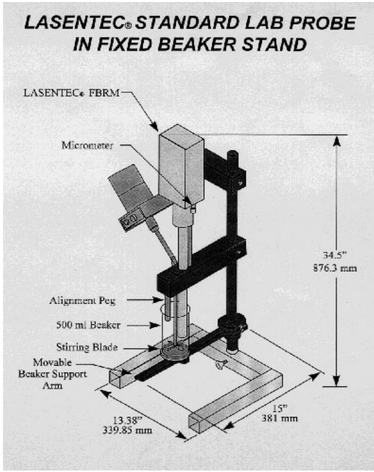

UCM
INGENIERÍA QUÍMICA
How to interpret the data
Effect of retention additives
PZ of pulp ↓
CD of WW ≈
Low WW turbidity
Good retention
DCM in WW
PZ of pulp ↓
CD of WW ↓
Low WW turbidity
Good retention
DCM with product
Clean process water
Ions
Fillers/fines
Anionic trash
Monash, 16th August 2018
9

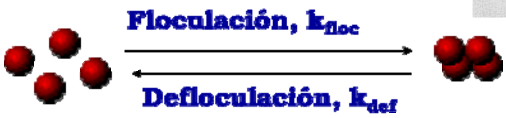
Wet-end optimization

Traditional techniques:
- **Based on electric properties**
  ➔ overdosification
- **Conditions ≠ real process**

Required techniques:
- **Based on particle size changes**
- **On real time and on line**

OBJECTIVES:
- **Study of flocculation mechanisms and floc properties**
- **Wet end optimization**

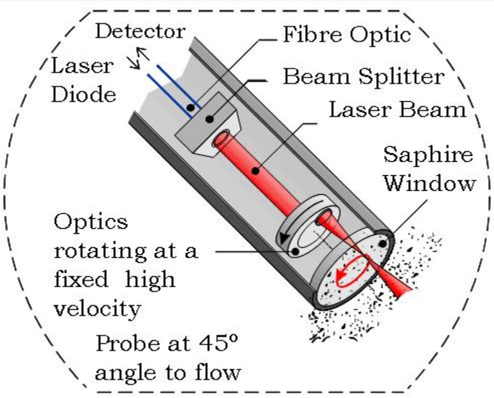


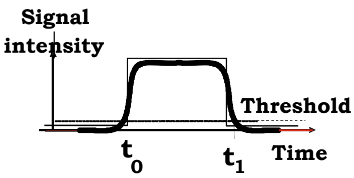


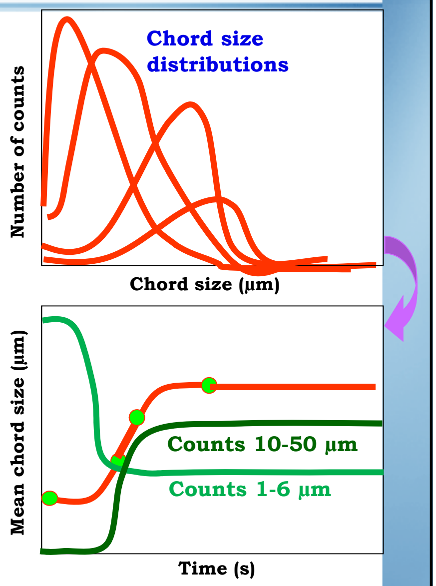
Monash, 16th August 2018

10

FBRM



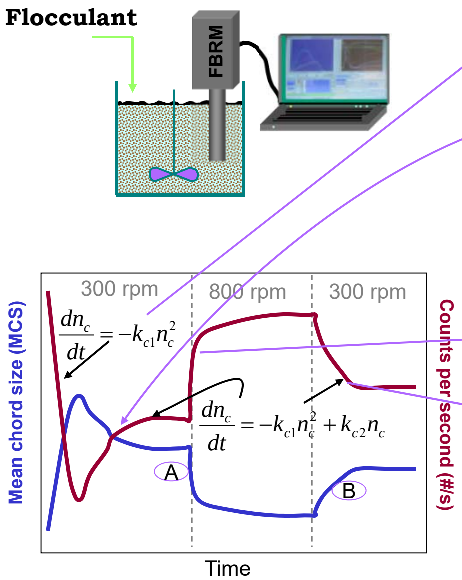




Monash, 16th August 2018

11

Flocculation methodology



FLOCCULATION
- Flocculant efficiency → k_{c1floc}
- Floc size
- Flocculant dosage

EVOLUTION
- Floc stability
- Reconformation
- Flattening $k_{c1evolut}/k_{c1floc}$
- Floc strength
  - k_{c2} ↑ → soft flocs
  - k_{c2} ↓ → hard flocs

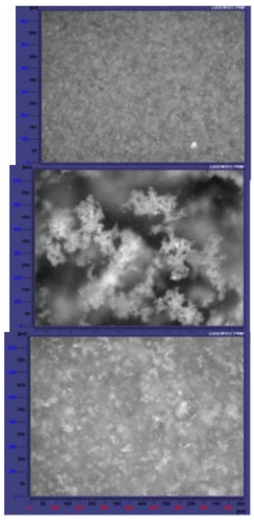
DEFLOCCULATION
- Floc strength at high shear stress

REFLOCCULATION
- Reflocculation ability
- $k_{c1refloc}/k_{c1floc}$
- ΔMCS_A / ΔMCS_B
- Flocculation mechanism

Monash, 16th August 2018

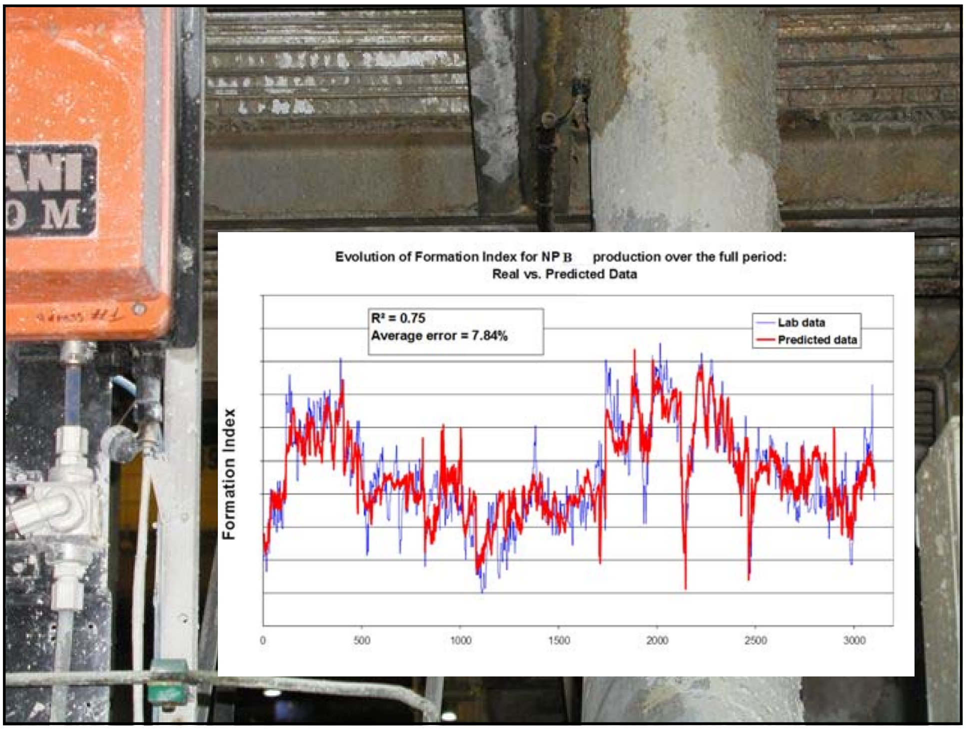
12

Wet end methodology



Monash, 16th August 2018

13



FBRM methodology

1994

Method to optimize the polymer dosage for flocculation using the particle size analyzer (FBRM). Blanco et al. 1994, PhD thesis U.C.M

Influence of closed system on chemical flocculation" Towards the Closed System-Threats and Opportunities. Blanco, PIRA International. Leatherhead, Inglaterra. 1 March 1994.

Flocculation control in papermaking". TAPPI Papermakers Conference. San Francisco, 24 April 1994.

Influence of salt on the interaction of polymers with the different pulp fractions". TAPPI Papermakers Conference. San Francisco, 24 de abril de 1994.

1996

FBRM as an alternative to ζ potential Blanco et al. 1996, Appita J. 49(2):113).

2002

FBRM to study the effect of DCM on flocculation Blanco et al. 2002, Tappi J. 1(10):14; Dunham et al. 2000, J. Pulp Pap. Sci. 26(3):95).

Flocculation-deflocculation-reflocculation kinetics and floc properties. Flocculation of DCM Blanco et al., 2002, Tappi J. 1(10):14; Blanco et al. 2002; CJChE. 80(4)734).

Monash, 16th August 2018

15

FBRM methodology

2003

2004

2005

2006

Flocculation of fillers, mechanisms Fuente et al. 2003, Pap. Technol. 44(8):41; Blanco et al. 2005, Ind. Eng. Chem. Res. 44(24):9105 Fuente et al. 2005, Ind. Eng. Chem. Res. 44(15):5616).

Flocculation in fiber-cement industry Negro et al., 2005, Cem. Concr. Res. 35:2095).

Flocculation mechanism induced by PEO/PFR dual system (Negro et al. 2005, AIChE J. 51(3):1022).

Optimization of the fiber-cement flocculation process with FBRM Negro et al. 2005, Composites A. 36(12):1617; Negro et al. 2006, Cem. Concr. Comp. 28(1):90; Negro et al. 2006, Chem. Eng. Sci. 61:2522

FBRM on line to predict fiber-cement product properties Negro et al. 2006, Ind. Eng. Chem. Res. 45(1):197).

Prediciton of paper properties based on wet end parameters Blanco et al. 2006 Int. RTA Users' Conf., Feb., Barcelona, Spain Control Systems 2006, Tampere, Finland).; Blanco et al, 2009, Math. Comp. Model. Dyn. 15(5):453

Comparative study of wet-end additives Cadotte et al. 2007, Can. J. Chem. Eng. 85(2):240; Hu and Hu, 2007, Res. Prog. Pap. Ind. Bioref., 1-3:1601.

Monash, 16th August 2018

16

FBRM methodology

2008

2009

2009

2013

2015

Separation of contaminants from deinking process water by dissolved air flotation: effect of flocculant charge density/ Miranda et al. 2008, Sep. Sci. Technol, 43(14):3732

Effect of fibre morphology on flocculation of fibre-cement suspensions. Tonoli et al. 2009, Cem. Conc. Res., 39(11):1017

Influence of water quality in the efficiency of retention aids systems for the paper industry Ordoñez et al. 2009, Ind. Eng. Chem. Res, 48:10247.

Influence of cationic starch adsorption on fiber flocculation Zakrajsek et al. 2009, Chem. Eng. Technol. 33(8):1259.

Polymeric Branched Flocculant on Flocculation in the Papermaking Blanco et al. 2009, Ind. Eng. Chem. Res 48(10):4826

Flocculation efficiency of chitosan for papermaking applications Nicu et al. 2013, Bioresources 8(1):768; Miranda et al. 2013 Chem.Eng.J, 231:304

Silica removal from newsprint mill effluents. Latour et al. CEJ 230:522-531

Influence of SS on silica removal by coagulation with aluminum salts. Miranda et al. CCT 49,497-510

Optimization of silica removal with magnesium chloride in papermaking effluents: mechanistic and kinetic studies. ESPR 23(4) 3707-3717.

Efficiency of polyaluminum nitrate sulphate-polyamine hybrid coagulants for silica removal. Desalin. Wat. Treat. 57(38) , 17973-17984.

Monash, 16th August 2018

17

FBRM methodology 2016 -1018

ooo

Evaluation of the flocculation and reflocculation performance of a system with calcium carbonate, cationic acrylamide co-polymers, and bentonite microparticles. Antunes et al. Ind. Eng. Chem. Res. 54(1), 198-206
Efficiency of chitosan and their combination with bentonite as retention aids in papermaking. Bioresources 11(4), 10448-10468.

Esterification of glycerol and ibuprofen in solventless media catalyzed by free CALB: Kinetic modelling. Ravelo et al. Biochem. Eng. J. 101, 228-236.
Experimental and modelling approach to the catalytic coproduction of glycerol carbonate and ethylene glycol as a means to valorize glycerol. J. Taiwan Inst. Chem. Eng. 63, 89-100.

Estimation of Chlamydomonas reinhardtii biomass concentration from chord length distribution data. J. Applied Phycology 28(4) 2315-2322.
Laser reflectance measurement for the online monitoring of Chlorella Sorokiniana biomass concentration. J. of Biotechnology, 243(2), 10-15. **Estimation fractal dimension of microalgal flocs through confocal laser scanning microscopy and computer modelling**. Algal Research-Biomass Biofuels and Bioproducts 28 (2017), 74-79

Effect of polyelectrolyte morphology and adsorption on the mechanism of nanocellulose flocculation. Raj et al. J. Coll. Interf. Sci. 481, 158–167
Microfibrilated cellulose as a model for soft colloid flocculation with polyelectrolytes. Raj et al. Colloids Surf. A. - Physicochemical and Engineering Aspects, 516, 325-335.
Synergies between cellulose nanofibers and retention additives to improve recycled paper properties and the drainage process. Cellulose, 24(7), 2987-3000.
Interactions between cellulose nanofibers and retention systems in flocculation of recycled fibers. Cellulose 24(2) (2017), 677-692

Monash, 16th August 2018

18

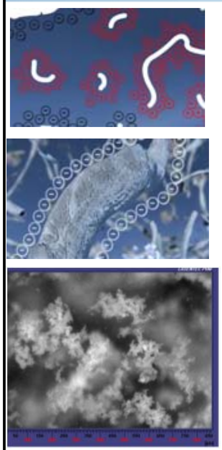
Content

- How to improve the effectiveness of papermaking chemicals.
- **Balance between retention and drainage.**
- Integration of water and retention system management.
- On-line wet end control.
- Wet-end audit: Case studies.

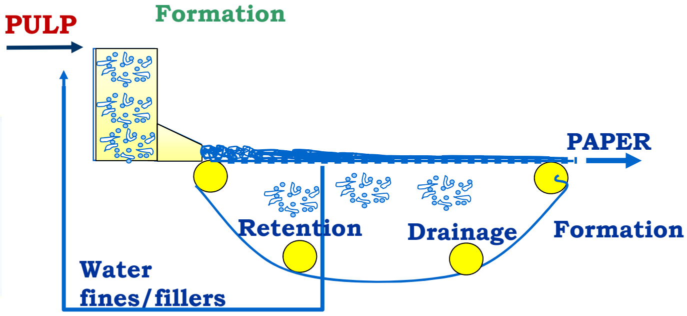
Monash, 16th August 2018

19

Wet-end optimization



Suspension characteristics: ZP, CD
Floc properties: size, number, characteristics
White water characteristics: turbidity, CD
Retention
Drainage
Formation



PAPERMAKING CHEMISTRY

Factors affecting coloidal stability:

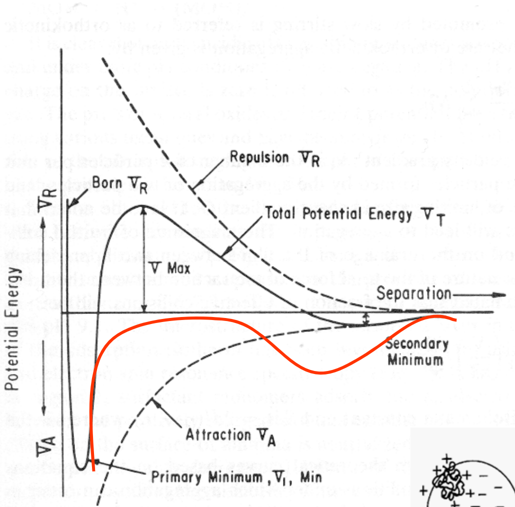
- Particle size
- Particle geometry and flexibility
- Surface properties:
  - Adsortion
  - Double electric layer
- Particle-particle interactions
- Particle-solvent interactions

Wet-end chemistry

Forces involved between particles

- **Repulsive forces:**
  - Electrostatic
  - Born
- **Attractive forces:**
  - Van der Waal forces
  - Lewis base-Lewis acid interactions
- **Brownian movement**
- **Steric stabilisation**

Wet-end chemistry

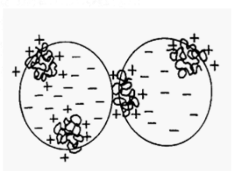


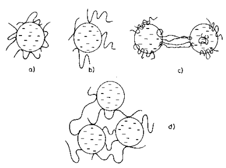
FLOCULATION → $F_A > F_R$

↓ Repulsive forces
➔ ξ reduction

Atractive forces
↑ ➔ Chemical interactions

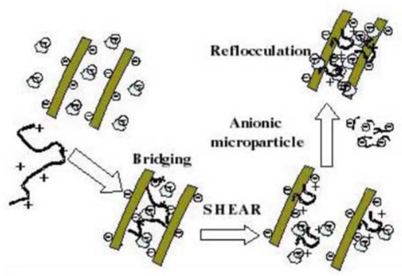
FLOCCULATION MECHANIMS
- **Neutralization**
- **Patching**
- **Bridging**
- **Complex**

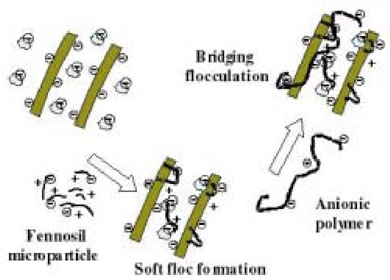




Retention systems

- Single polymers: PEI, PA (patch) o PAM (bridges).
- Dual systems: PEI + PAM ➔ patch + bridges.
- 2-3 components with micro/nano-particles: silica, bentonite or organic micropolimers.
- Non-ionic systems: PEO/cofactor (phenolic resin).



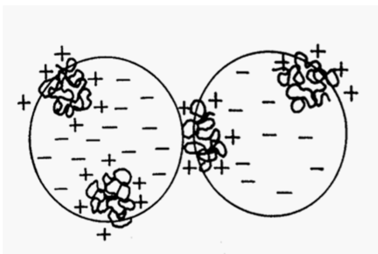


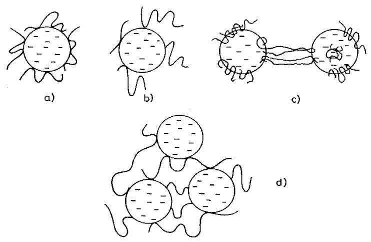
Monash, 16th August 2018

25

Wet-end chemistry

FLOC PROPERTIES



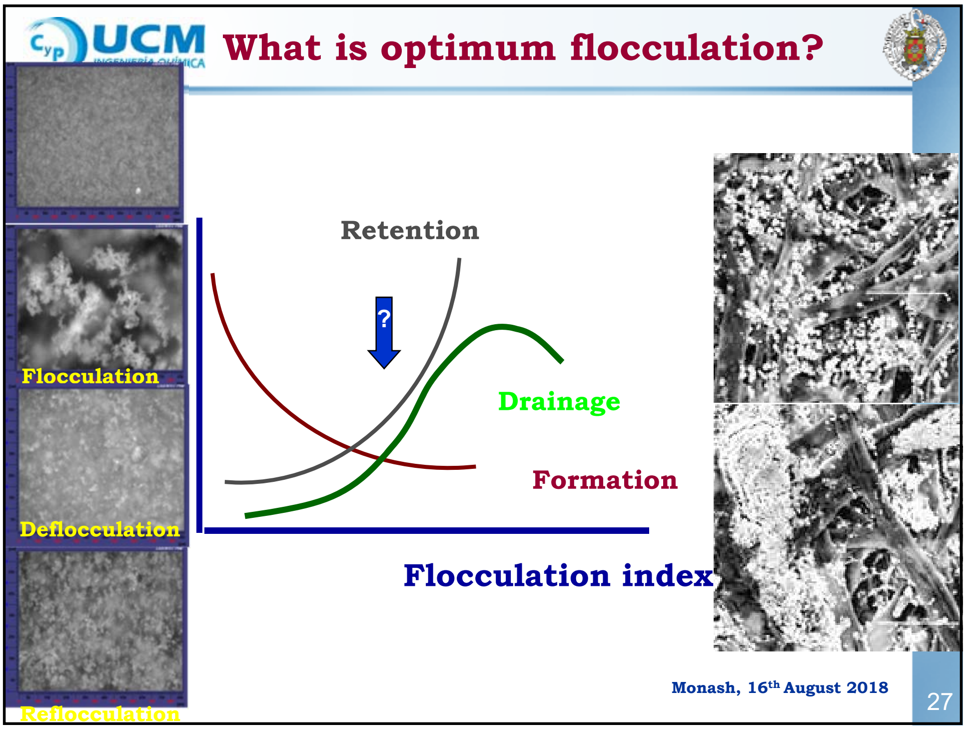


SOFT FLOCS
- Easy to break down
- Reflocculation
- More compact

HARD FLOCS
- Difficult to break down
- Partial reflocculation
- More voluminous

Monash, 16th August 2018

26



UCM INGENIERÍA QUÍMICA

What is optimum flocculation?

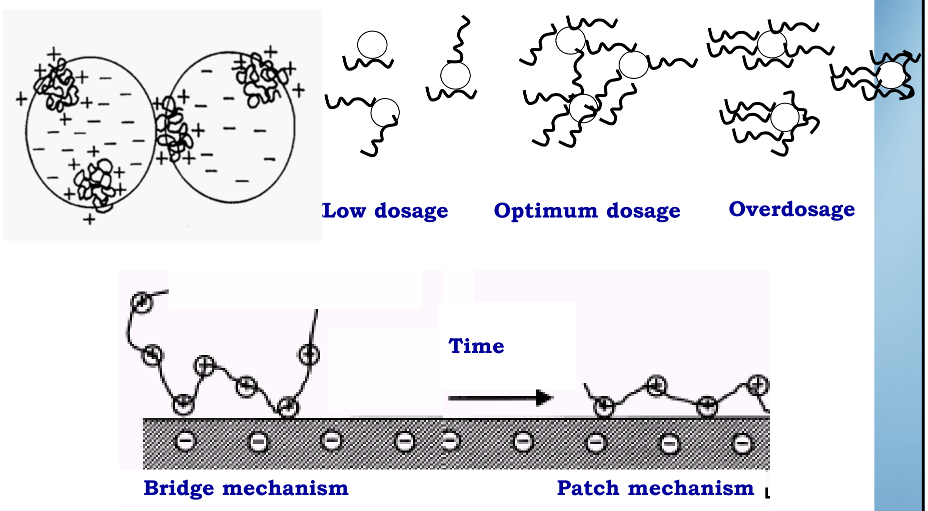
Cualitative relationships between flocs and papermaking processes

INFLUENCE	POSITIVE
PROCESS	
Drainage (foils)	Big and compact flocs
Drainage (vacuum)	Small and compact flocs
Drainage (press)	Soft flocs
Retention	Fiber-filler flocs
PRODUCT	
Formation	Small and compact flocs
Porosity	Small flocs
Strength	Small flocs

Monash, 16th August 2018

28

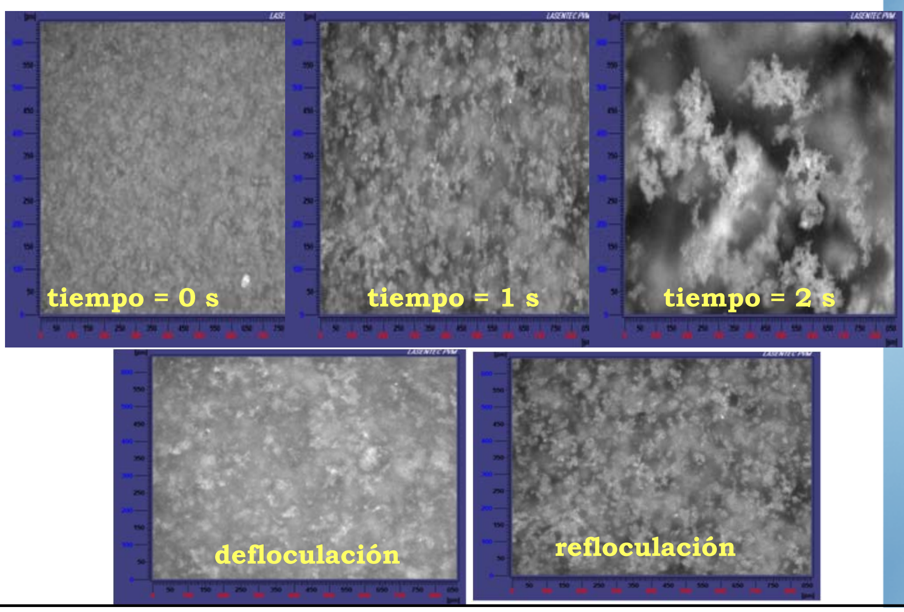
Effect of flocculant dosage & time



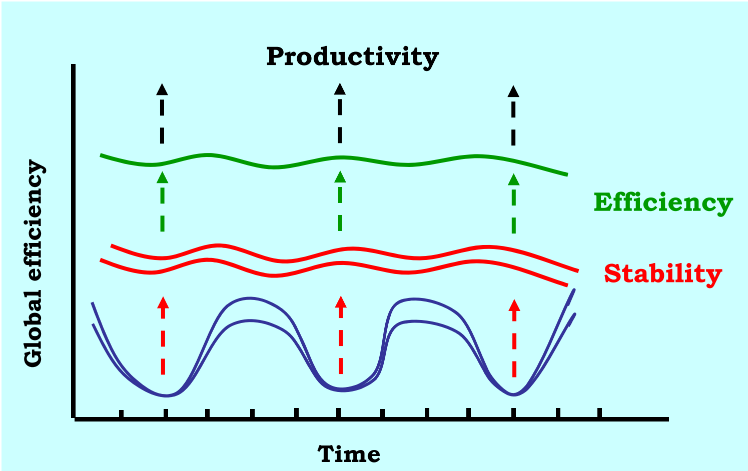
Monash, 16th August 2018

29

Dosification point



Challange: stability & efficiency



Monash, 16th August 2018

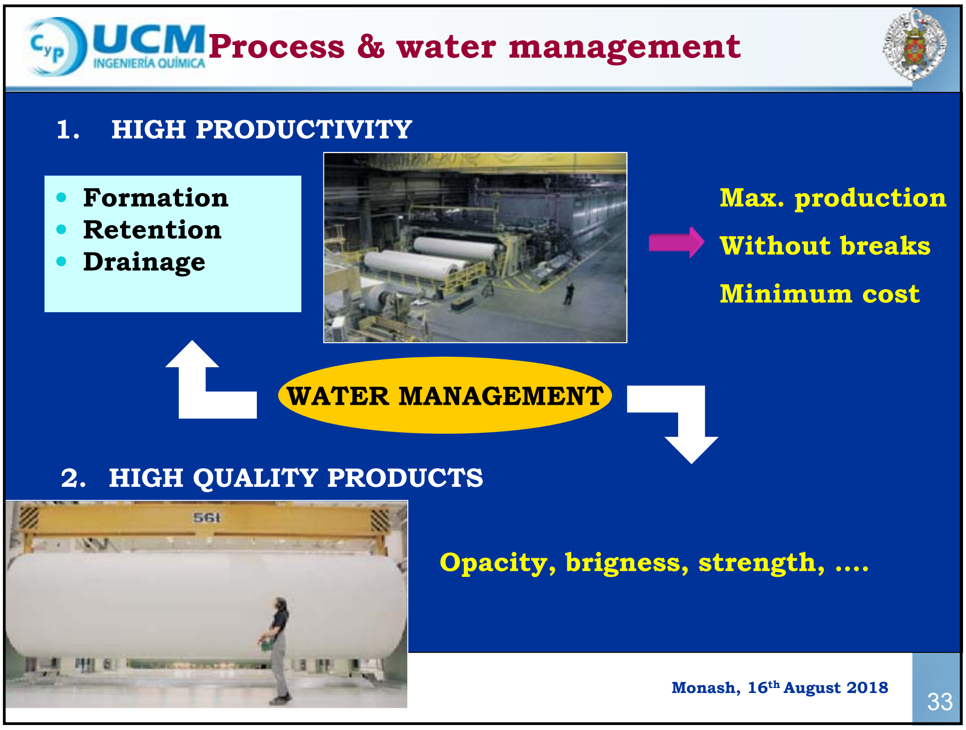
31

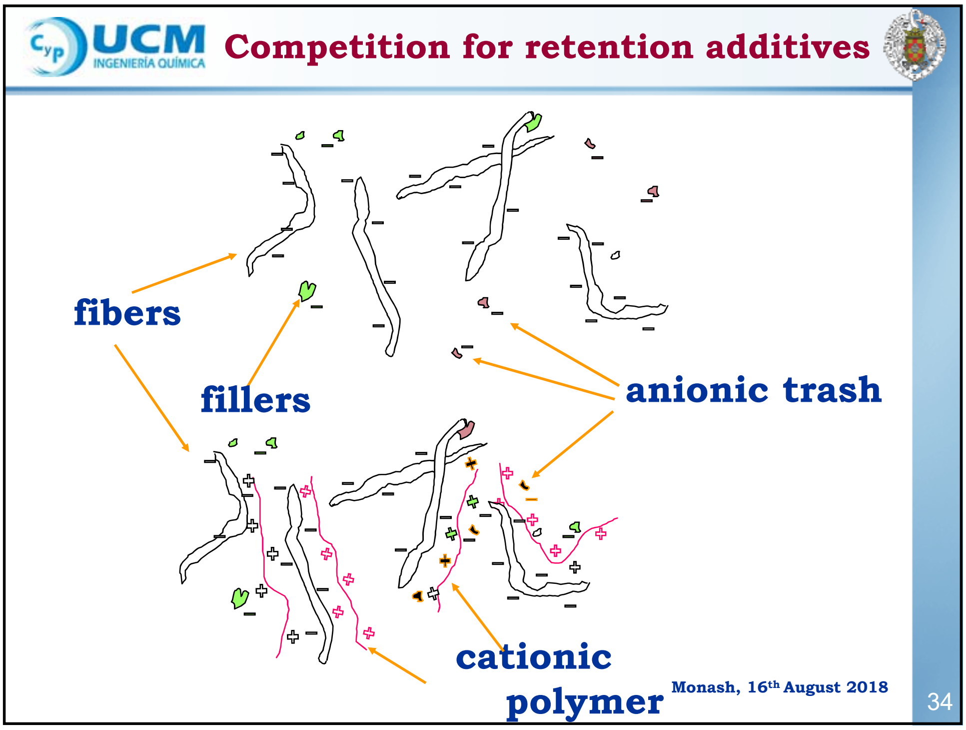
Content

- How to improve the effectiveness of papermaking chemicals.
- Balance between retention and drainage.
- **Integration of water and retention system management**
- On-line wet end control.
- Wet-end audit: Case studies.

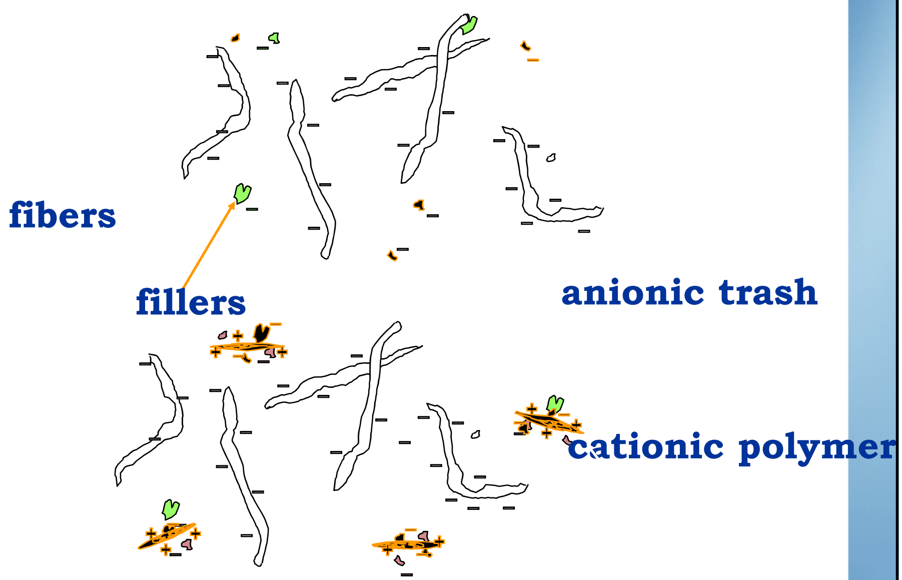
Monash, 16th August 2018

32


UCM INGENIERÍA QUÍMICA
Process & water management
1. HIGH PRODUCTIVITY
Formation
Retention
Drainage
Max. production
Without breaks
Minimum cost
WATER MANAGEMENT
2. HIGH QUALITY PRODUCTS
Opacity, brigness, strength, ….
Monash, 16th August 2018
33


UCM INGENIERÍA QUÍMICA
Competition for retention additives
fibers
fillers
anionic trash
cationic
polymer
Monash, 16th August 2018
34

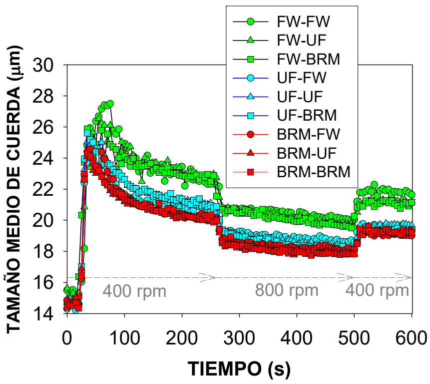
Competition for retention additives

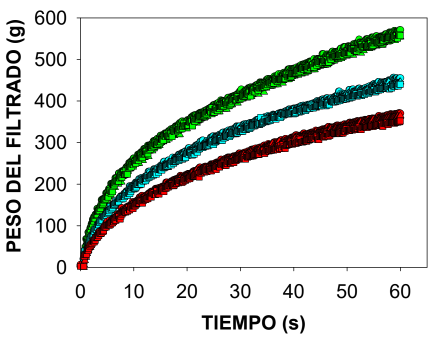


Monash, 16th August 2018

35

Water quality vs flocculation and drainage





FLOCCULATION

- **Larger chord lengths with FW.**
- **Similar floc reversibility**
- **Bentonite ≠ f (water quality.**

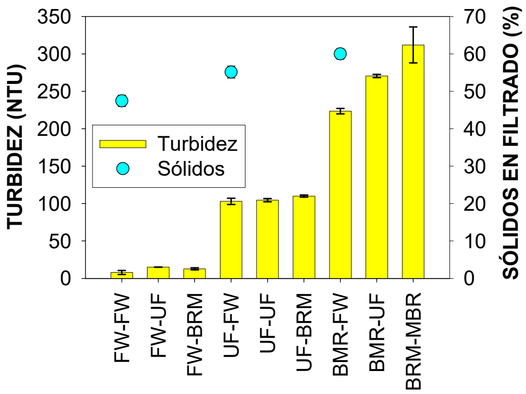
DRAINAGE

- **Lower drainage time with FW.**
- **Bentonita ≠ f (water quality).**

Monash, 16th August 2018

36

Water quality vs flocculation and drainage



↑ CD
(soluble anionic contaminants)

Interaction with cationic groups of PAM

↓ charge density

Weaker interaction with fillers, fines and fibers

Smaller flocs

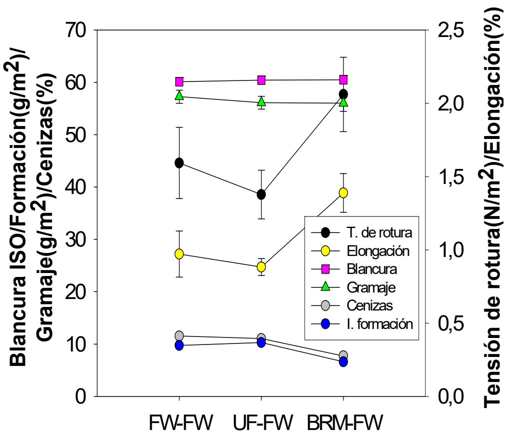
Higher WW turbidity

Low ash retention

Monash, 16th August 2018

37

Water quality vs flocculation and drainage



MBR water

↓ ash and fines retention

↓ paper ash

Lower ash

\+ mechanical strength

↑ % elongation
↑ breaking length

Small flocs

↓ Formation index
Better formation

Gramage, whiteness ISO → no effect

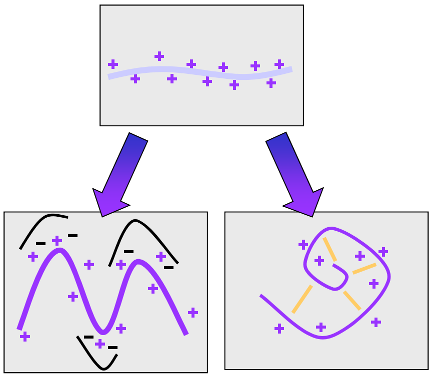
FW y UFW → similar parameters

Monash, 16th August 2018

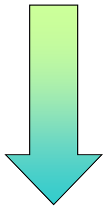
38

Effects of DCM accumulation

Reduction of the additive efficiency



DCM agglomeration



DEPOSITS

Monash, 16th August 2018

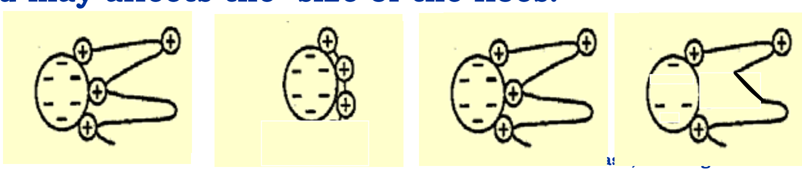
39

Effects of salts

- If conductivity increases agglomeration is induced and the required dosages of flocculant decrease.
- Polymer conformation may change and flocculation mechanism shifts towards a charge model. The polymer is still effective but produce smaller flocs.

  ↓ Bridges ⇒ ↓ big flocs

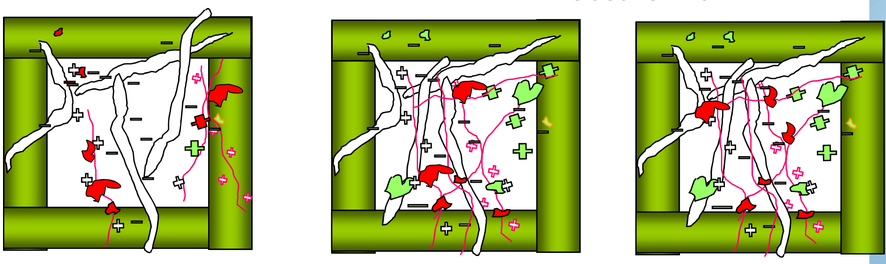
- High ionic strength partially neutralise the polymer charge which reduced the adsorption of polymer and may affects the size of the flocs.



40

Efficiency of polymers in closed circuits

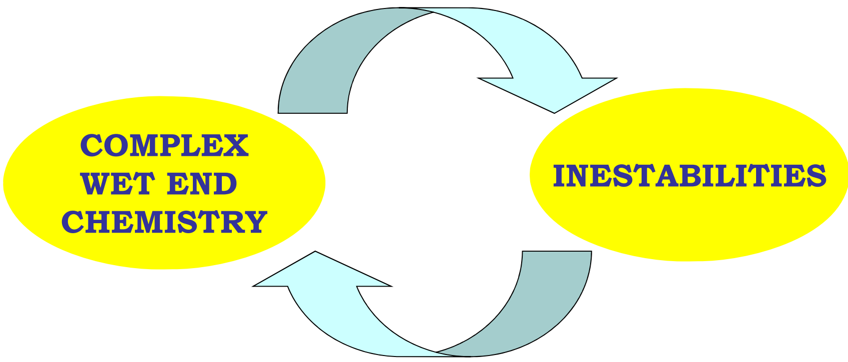
Low dosage Cost: A1	High dosage Cost: A2	1.-Coagulant thick stock 2.-Ret. aid low dosage Cost: C+A3



PZ ≈ DC of WW ↓ Retention ↓	PZ of pulp ↓ DC of WW ↓ Retention ↑	DC ↓ PZ ≈ DC ≈ PZ ↓ Retention ↑ Cost < A2

Monash, 16th August 2018

41



Monash, 16th August 2018

43

UCM INGENIERÍA QUÍMICA

Content

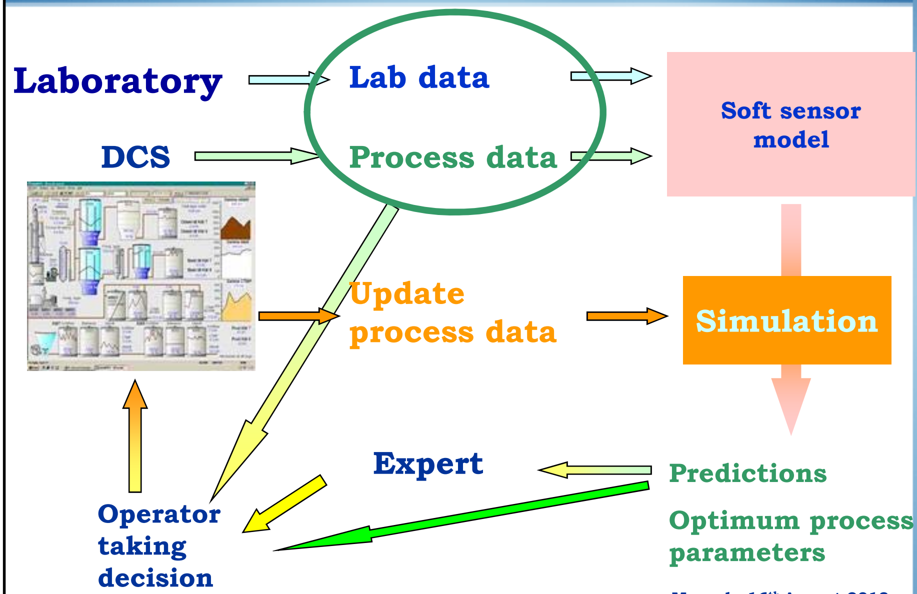
- How to improve the effectiveness of papermaking chemicals.
- Balance between retention and drainage.
- Integration of water and retention system management
- **On-line wet end control.**
- Wet-end audit: Case studies.

Monash, 16th August 2018

44

UCM INGENIERÍA QUÍMICA

On-line wet end control



Monash, 16th August 2018

45

UCM INGENIERÍA QUÍMICA

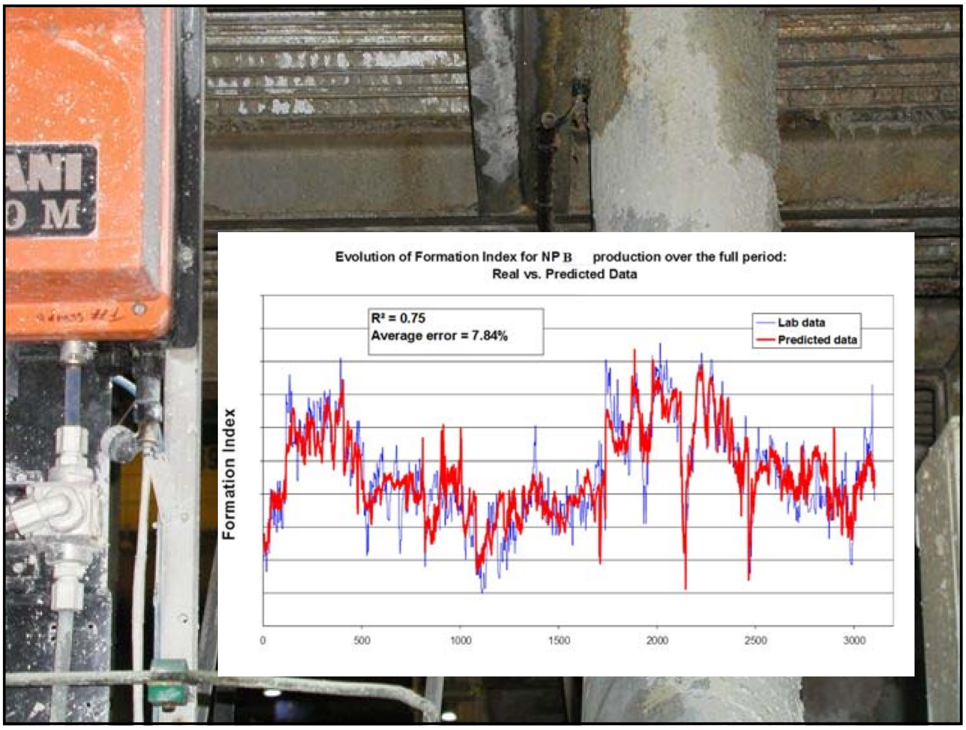
Wet end variables

VARIABLE	UNIDS.	VARIABLE	UNIDS.
Cons. Caja Entrada (DCS) PM61	g/l	Gramaje (PaperLab) PM61	g/m^2
Cons. Caja Entrada (Lab) PM61	%	Espesor (PaperLab) PM61	µm
Cenizas caja entrada (DCS) PM61	g/l	Indice Formación (PaperLab) PM61	
Cenizas caja entrada (Lab) PM61	%	Rcia. Tracción (PaperLab) PM61	kN/m
Cons. Ag. Blancas (DCS) PM61	g/l	Rcia. Desgarro (PaperLab) PM61	Nm^2/kg
Cons. Ag. Blancas (Lab) PM61	%	Elongación (PaperLab) PM61	
Cenizas Ag. Blancas (DCS) PM61	g/l	Densidad (PaperLab) PM61	kg/m^3
Cenizas Ag. Blancas (Lab) PM61	%	Hand (PaperLab) PM61	cm^3/g
Retención total (DCS) PM61	%	Longitud de rotura (PaperLab) PM61	km
Retención total (Lab) PM61	%	Long. TEA (PaperLab) PM61	J/m^2
Retención cenizas (DCS) PM61	%	Longitudinal TSI (PaperLab) PM61	kNm/g
Retención cenizas (Lab) PM61	%	Transversal TSI (PaperLab) PM61	kNm/g
Índice de floculación PM61		Porosidad (PaperLab) PM61	ml/min
Destintado2 Caudal	m^3/h	Opacidad (PaperLab) PM61	%
Destintado3 Caudal	m^3/h	Brillo (PaperLab) PM61	%
Caudal rotos	m^3/h	Humedad en parte final de PM61	%
Dosis floculante PM61	g/Ton	Cenizas base en papel PM61	%
Dosis coagulante PM61	g/Ton	Cenizas en parte final de PM61	%
Dosis micropartícula PM61	g/Ton	Humedad en Prensa PM61	%
Dosis $CaCO_3$ PM61	l/h	cps (1-5 µm)	Cts/s
Velocidad cable PM61	m/min	cps (5-34 µm)	Cts/s
pH en PIT		cps (34-1000 µm)	Cts/s
		Media, 1/Lin Pond.	µm
		Media, Cuad. Pond.	µm
		Mediana.	µm
		%<5.41	%
		%>34.15	%

Monash, 16th August 2018

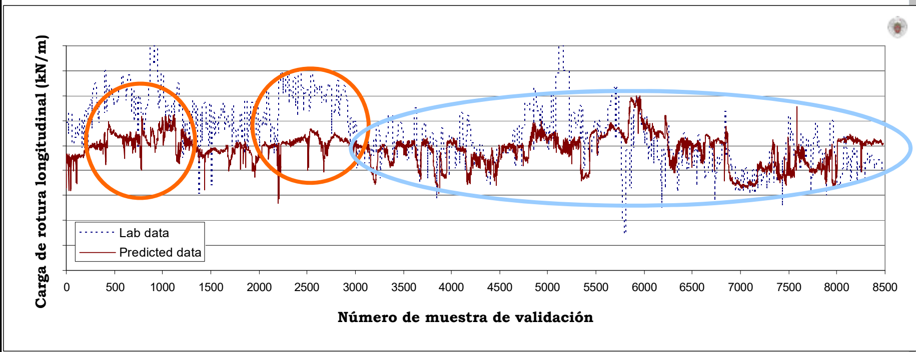
1.Objetivo | 2.Procesos | 3.Herramtas. | 4.Metodolog. | 5a.Res.Fibr. | 5b.Res.Papel | 6.Conclus.

46



Predictions 3-6 months after model building

- Most of the production has the predicted data.
- Some periods have higher prediction error due to changes in the operating conditions.

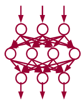


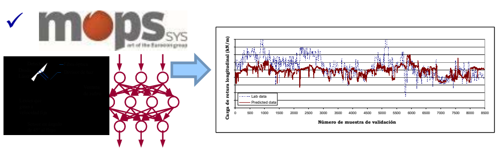
	Carga de rotura longitudinal	Longitud de rotura longitudinal	Índice de formación
Error medio (ε) (%)	13	17	9

Monash, 16th August 2018

Improved paper properties Advance data analysis

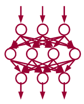
- On-line data
- FBRM data
- Paper quality data





✓ Better prediction→ Formation index
✓ FBRM → 25% improvement

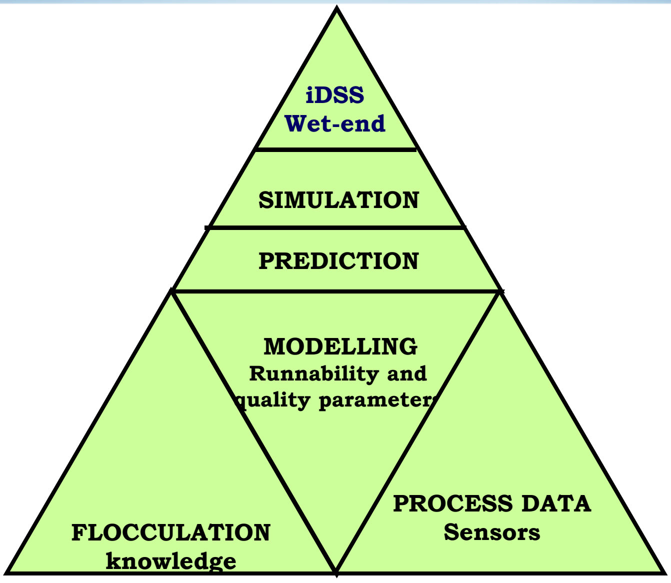
	Carga de rotura longitudinal	Longitud de rotura longitudinal	Índice de formación
Error medio (ε) (%)	9.0	7.6	4.4



✓ Training ANN: Levenberg-Marquardt algorim.
✓ ANN model: 1 layer of 3 to 7 neurons.
✓ Validation: Mix with 40% to 60% external data
✓ Training time: 3 months.
✓ Automatic up-date

Monash, 16th August 2018

Wet-end vision



Monash, 16th August 2018

50

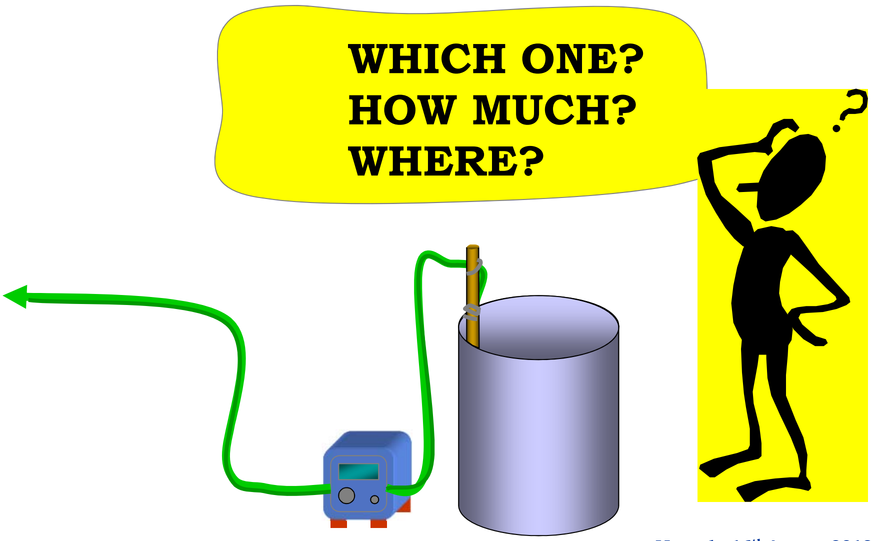
Content

- How to improve the effectiveness of papermaking chemicals.
- Balance between retention and drainage.
- Integration of water and retention system management
- On-line wet end control.
- **Wet-end audit: Case studies.**

Monash, 16th August 2018

51

Wet end optimization



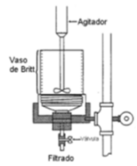
Monash, 16th August 2018

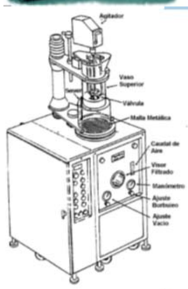
52

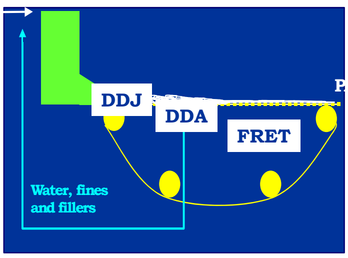
Wet-end audit methodology
Retention-Drainage-Formation

RETENTION & DRAINAGE STUDIES

- **GRAVITY**
  - **DDJ**
- **VACUUM**
  - **Dynamic drainage analyzer DDA**
  - **Formation and retention tester (FRET)**

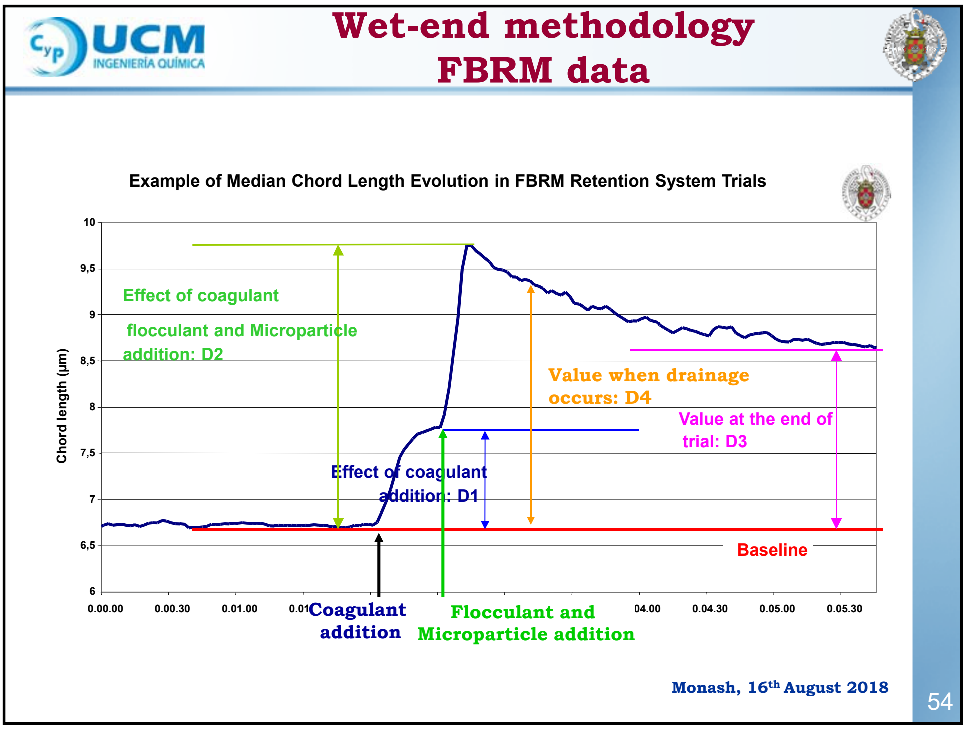


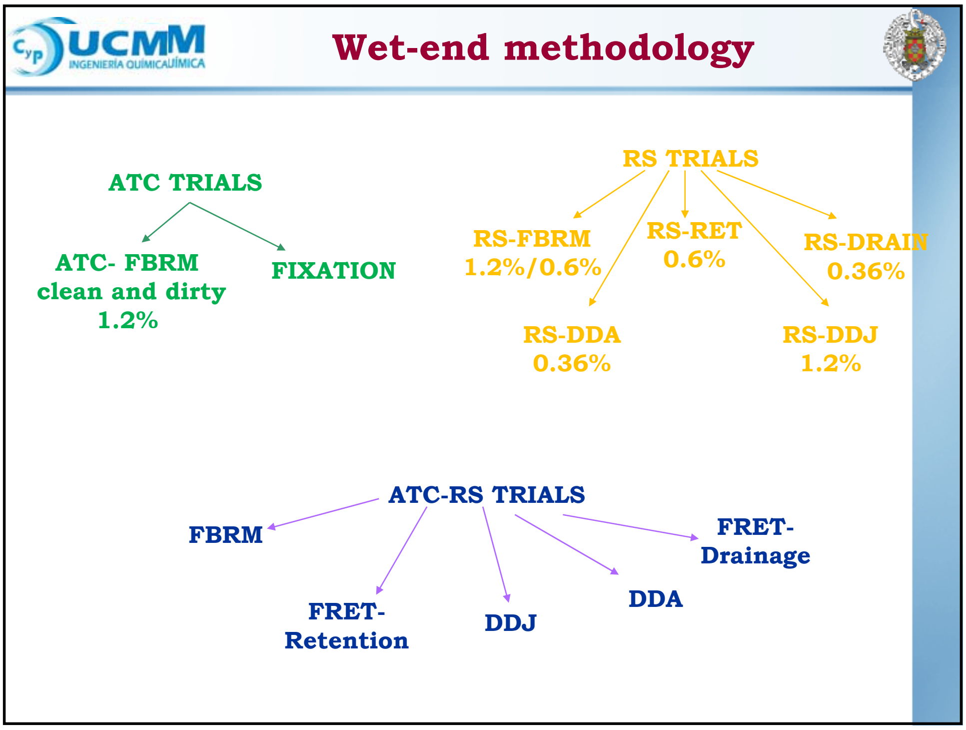




Monash, 16th August 2018

53


UCM INGENIERÍA QUÍMICA
Wet-end methodology
FBRM data
Example of Median Chord Length Evolution in FBRM Retention System Trials
Chord length (µm)
10
9,5
9
8,5
8
7,5
7
6,5
6
Effect of coagulant
flocculant and Microparticle
addition: D2
Value when drainage
occurs: D4
Value at the end of
trial: D3
Effect of coagulant
addition: D1
Baseline
0.00.00
0.00.30
0.01.00
0.01
04.00
0.04.30
0.05.00
0.05.30
Coagulant
addition
Flocculant and
Microparticle addition
Monash, 16th August 2018
54


UCM INGENIERÍA QUÍMICA
Wet-end methodology
ATC TRIALS
ATC- FBRM
clean and dirty
1.2%
FIXATION
RS TRIALS
RS-FBRM
1.2%/0.6%
RS-RET
0.6%
RS-DRAIN
0.36%
RS-DDA
0.36%
RS-DDJ
1.2%
ATC-RS TRIALS
FBRM
FRET-
Drainage
FRET-
Retention
DDJ
DDA

Wet-end methodology

ATC-FBRM:
- Mean chord length
- Total counts/s
- > 58 µm evolution
- <5 µm evolution

RS-RET:
- Turbidity
- CD
- Gramage
- Total retention
- Ash retention
- Formation

RS-DDA:
- Drainage time
- Permeability
- Drainage curve
- Turbidity

RS-FBRM:
- Mean chord length
- Total counts/s
- >58 µm evolution
- <5 µm evolution

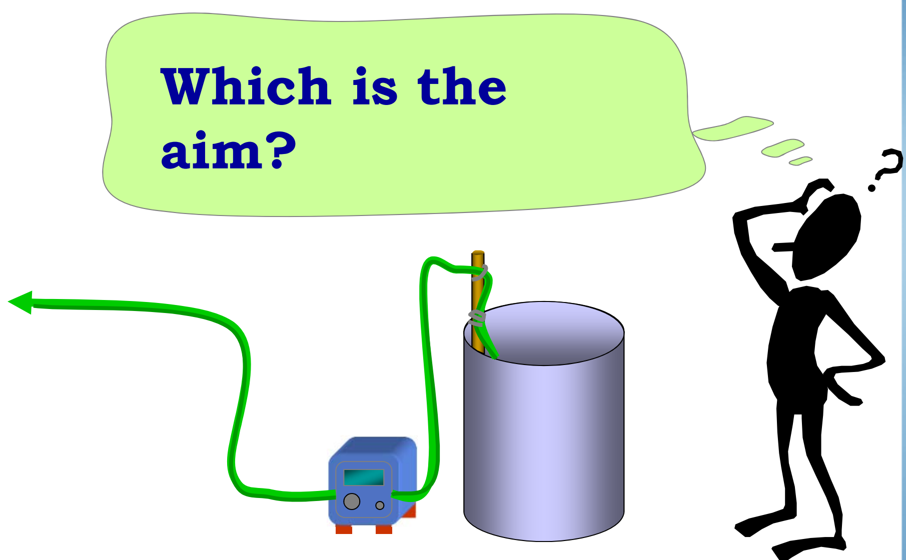
RS-DRAIN:
- Residual vacuum
- Total area
- Area > Tmax
- Total retention
- Ash retention
- Formation
- FBRM

RS-DDJ:
- Drainage time (100 mL)
- Turbidity
- Total retención
- Ash retención

Monash, 16th August 2018

56

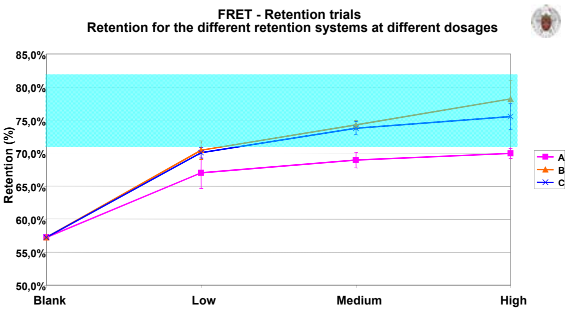
CASE STUDIES

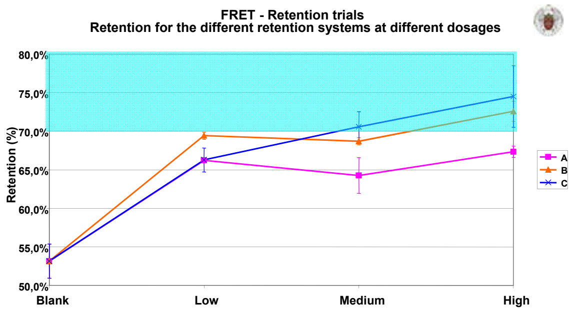


Monash, 16th August 2018

57

Case 1
Retention study





B = C > A

Case 2
Selection of retention systems

Trials	Variable	RS A			RS B			RS C			Errors
18/05/04	Dosage	Low	Medium	High	Low	Medium	High	Low	Medium	High	
RS DDJ	Drain Time	19,5	18,3	14,3	28,7	28,5	14,7	15,0	8,3	9,7	Low
	Turbidity	5943	3460	3910	4260	3485	1692	2379	2228	2992	Very Low
	Total Retention	89,4%	86,1%	85,6%	80,4%	84,1%	89,2%	90,2%	91,9%	89,6%	Medium
	Ash Retention	82,1%	77,1%	73,1%	71,0%	78,6%	80,7%	85,2%	85,0%	78,8%	Low
RS DDA	Drainage Time	-1	1	2	-1	-1	-1	-1	0	1	Very Low
	Permeability	0	-1	-1	0	0	0	1	0	0	High
RS RET	Turbidity	3480	2611	2413	2681	3120	1942	2889	2192	1807	Low
	CD	79,9	85,4	63,5	49,8	70,3	65,2	86,6	81,5	68,0	Low
	COD	411	415	392	393	413	426	412	406	444	Too High
	Grammage	53,04	51,65	54,18	55,46	55,02	58,20	53,25	56,55	59,68	Low
	Retention	66,2%	64,2%	67,3%	69,4%	68,7%	72,6%	66,3%	70,6%	74,5%	Low
	Form Index	27,37	24,75	21,63	26,05	25,13	20,53	27,40	23,73	20,73	Low
	HST DEV IF	5,68	6,33	7,02	5,78	6,10	7,48	5,57	6,44	7,24	Very Low
	Ash Content										Very Low
RS DRAIN	V res	108	133	104	172	143	134	173	157	138	Medium
	Total area	1598	2043	1898	2315	2091	1947	2470	2231	1992	Low
	Area >Tmax	1454	1874	1734	2146	1928	1782	2299	2066	1834	Medium
	%Area >Tmax	91,0%	91,8%	91,3%	92,7%	92,2%	91,5%	93,1%	92,6%	92,1%	Low
	Grammage	54,36	52,55	50,81	58,87	53,06	57,43	57,79	61,09	57,91	High
	Total Retention	67,7%	65,0%	63,1%	73,1%	65,7%	72,1%	71,6%	76,3%	74,3%	Medium
	Form Index	25,9	34,5	35,9	26,1	29,5	28,0	24,6	23,8	26,8	Low
	HST DEV IF	6,3	4,5	4,2	5,7	5,2	5,5	6,1	6,6	5,6	Low
	Ash Content	24,5%	20,5%	21,9%	26,5%	23,9%		26,7%	27,9%		Very Low
	D2TM	2	6	7	4	5	5	2	3	8	Low
RS FBRM	D4TM	3,5	4,5	5,5	3	3,5	4		4,5	6,5	Very Low
	D4 FN	3,8	4,5	4,8	3,8	4	4,3		5	6	Very Low

Monash, 16th August 2018

59

UCM INGENIERÍA QUÍMICA

Case 2
Selection of retention system

Trials	Variable	RS A			RS B			RS C			Errors
18/05/2004	Dosage	Low	Medium	High	Low	Medium	High	Low	Medium	High	
RS DDJ	Drain Time	19,5	18,3	14,3	28,7	28,5	14,7	15,0	8,3	9,7	Low
	Turbidity	5943	3460	3910	4260	3485	1692	2379	2228	2992	Very Low
RS DDA	Drainage Time	4,1	4,3	4,1	4,2	3,8	3,5	3,9	3,3	3	Very Low
RS RET	Turbidity	3480	2611	2413	2681	3120	1942	2889	2192	1807	Low
	Retention	66,2%	64,2%	67,3%	69,4%	68,7%	72,6%	66,3%	70,6%	74,5%	Low
	Form Index	27,37	24,75	21,63	26,05	25,13	20,53	27,40	23,73	20,73	Low
RS DRAIN	Area >Tmax	1454	1874	1734	2146	1928	1782	2299	2066	1834	Medium
	Total Retention	67,7%	65,0%	63,1%	73,1%	65,7%	72,1%	71,6%	76,3%	74,3%	Medium
	Form Index	25,9	34,5	35,9	26,1	29,5	28,0	24,6	23,8	26,8	Low
	Ash Content	24,5%	20,5%	21,9%	26,5%	23,9%		26,7%	27,9%		Very Low
	D2TM	2	6	7	4	5	5	2	3	8	Low
RS FBRM	D4TM	3,5	4,5	5,5	3	3,5	4		4,5	6,5	Very Low

Good drainage and formation

Good retention

Monash, 16th August 2018

60

UCM INGENIERÍA QUÍMICA

Case 3
Wet end audit- Optimization of costs

Trials	Variable	RS A			RS B			RS C			Errors
31/05/2004	Dosage	Low	Medium	High	Low	Medium	High	Low	Medium	High	
RS DDJ	Drain Time	62	20	18	53	25	25	40	22	25	Medium
	Turbidity	4558	5105	3885	4485	4185	2932	3788	4800	3352	Very Low
RS DDA	Drainage Time	4,86	5,53	4,45	4,99	4,54	3,64	4,79	4,05	4,84	Low
	Turbidity	1808	1580	1638	1550	1623	1448	1543	1502	722	Low
RS RET	Turbidity	4130	3077	2548	2835	2327	1458	2689	2452	2068	Very Low
	Retention	67,0%	69,0%	70,0%	70,4%	74,2%	78,2%	70,0%	73,8%	75,5%	Low
	Form Index	32,4	29,87	26,2	32,3	27,97	24,73	32,2	27,87	26,5	Low
	Ash Retention	26,2%	28,9%	31,1%	29,5%	35,2%	41,0%	31,5%	35,0%	38,2%	Very Low
	Area >Tmax	2487	2525	2119	3064	2792	2553	2920	2658	2497	Medium
	Total Retention	74,3%	76,4%	78,6%	74,0%	73,8%	81,2%	76,8%	75,9%	81,1%	Low
	Form Index	28,63	27,5	23,55	34,4	30,4	24,3	31,27	30,57	27,43	Low
	Ash Retention	66,3%	71,7%	72,7%	56,6%	63,7%	80,4%	70,5%	73,8%	83,9%	Low
RS FBRM	D4TM	1,6	2,1	2,9	1,7	2	3	1,7	2,2	4	Very Low

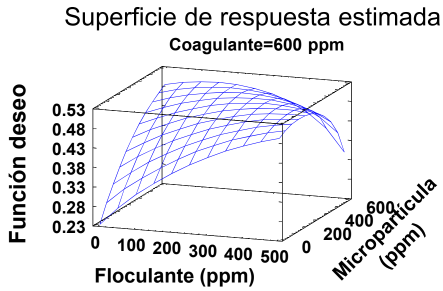
Good results

A cost study is required

Monash, 16th August 2018

61

Case 3
Wet end audit- Optimization of costs

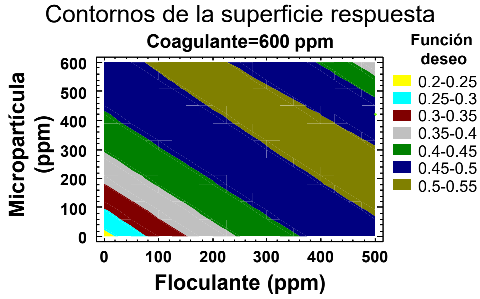


Optimised variables:

- **D2 maximun**
- **D3 maximum**
- **Minimun cost**

Stimated optimun:

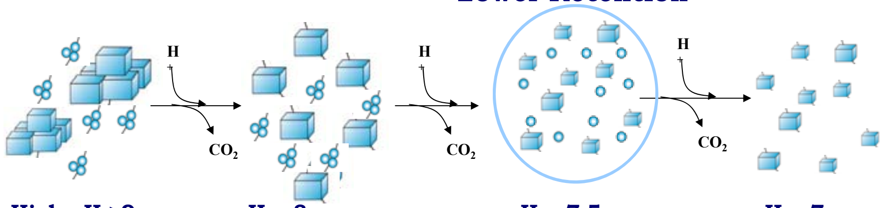
- **Coagulant = 0 ppm**
- **Floculant = 500 ppm**
- **Microparticle = 422 ppm**



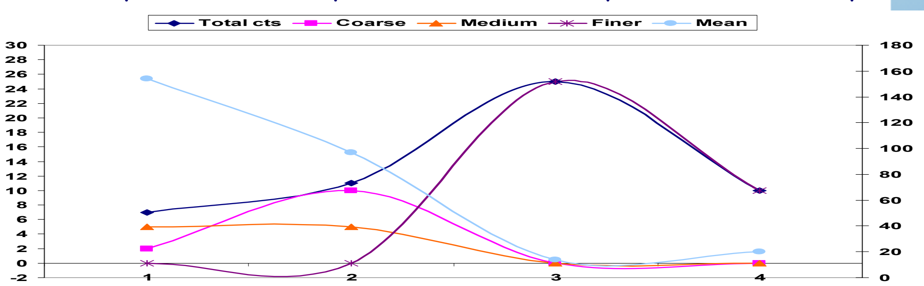
62

Case 4
Understanding pH effects

Lower Retention



High pH >9	pH = 8	pH = 7.5	pH = 7
7 particles:	11 particles:	25 particles:	10 particles:
2 big (500 µm),	10 big (100 µm),	10 small (20 µm),	10 small (20 µm),
5 medium (30µm)	5 medium (30 µm)	15 small (10 µm)	0 small
Mean: 154 µm	Mean: 97 µm	Mean: 14 µm	Mean: 20 µm




UCM
INGENIERÍA QUÍMICA
WET END OPTIMIZATION SEMINAR
A. Blanco and C. Negro
Complutense University of Madrid