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New advances in modelling of fibre suspension flow using a pseudo-homogeneous approach

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cost

1. Objectives
2. Experimental data
3. Geometry
4. Previous studies
5. LRN turbulence models modifications
6. Numerical results
7. Viscosity *new expression*
8. Conclusions
9. Future work

Development of a mathematical model to describe properly the flow of concentrated fiber suspensions in pipes

- **Adapt low-Reynolds *k-ε* (LRN) turbulence models** to take into account the presence of fibers
- **Validation of the model**

- **Flow rig**: test section (D=7.62cm, L=4m); magnetic flowmeter; differential pressure meter; temperature control and EIT rings.

- **Main results**: pressure drop, velocity and fiber concentration profile.

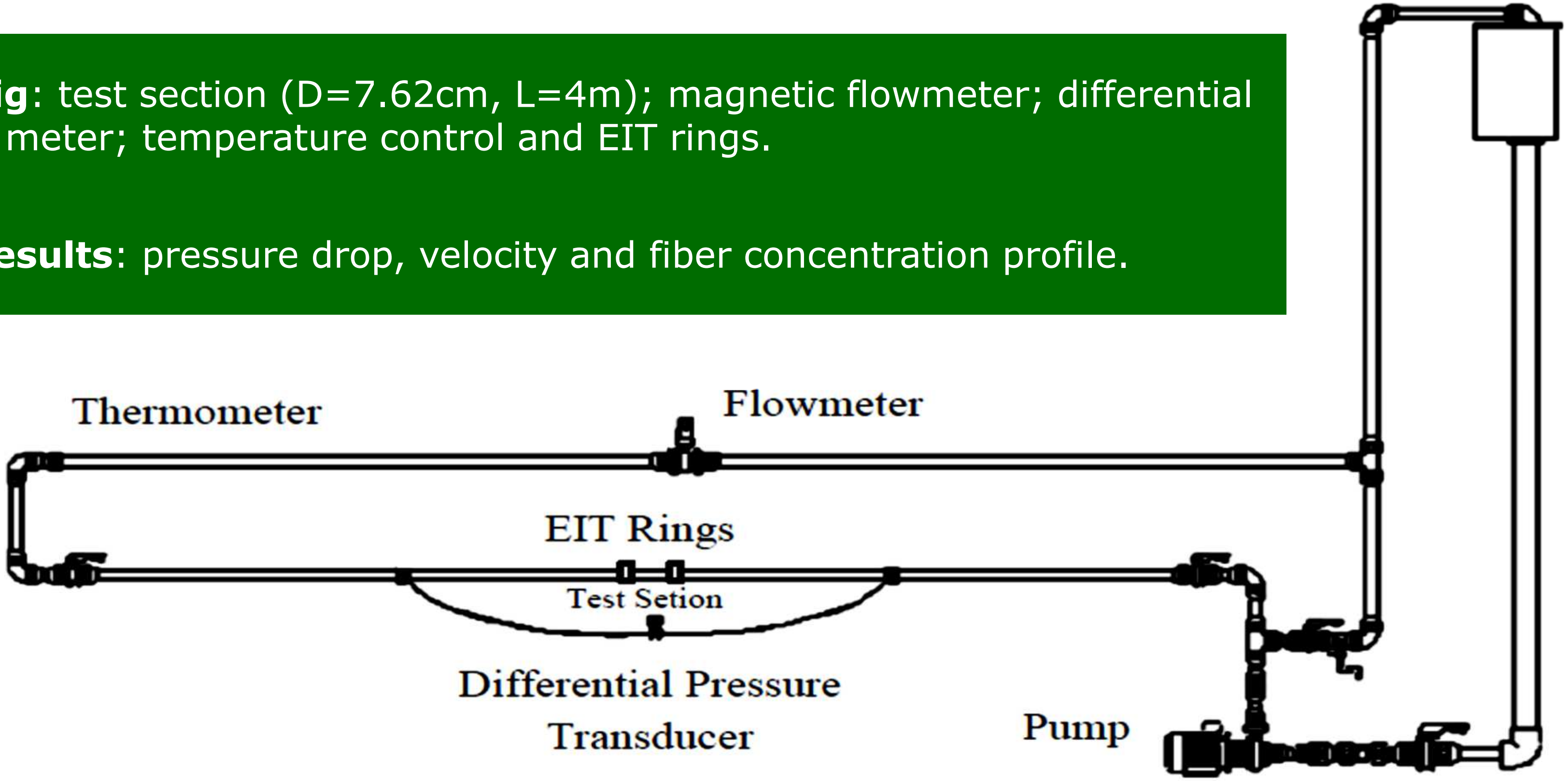


Figure 1 - Schematic view of the pilot (adapted from Ventura *et al* (2008) and Faia *et al* (2012)).

Faia, P.; Silva, R.; Rasteiro, M.; Garcia, F.; Ferreira, A.; Santos, M.; Santos, J.; Coimbra, P. (2012) – *"Imaging Particulate Two-Phase Flow in Liquid Suspensions with Electric Impedance Tomography"* – Particulate Science and Technology, 30(4): 329-342
Ventura, C.; Garcia, F.; Ferreira, P.; Rasteiro, M. (2008) – *"Flow Dynamics of Pulp Fiber suspensions"* – TAPPI Journal, 7(8): 20-26

Eucalyptus pulp suspension

- Fiber length = 0.706 mm
- ρ = 998.2 kg·m^{-3}

Table 1 – Experimental information.

c [% w/w]	*N* Crowding factor	Case	U_{in} [m·s^{-1}]	$\Delta P/L_{exp.}$ [Pa·m^{-1}]
1.50	1947	**A**	4.49	829
		B	6.21	1289
2.50	3245	**C**	4.90	2299
		D	5.55	2814

Crowding factor

$$N = \frac{2}{3} c_V \left(\frac{L_{fiber}}{D_{fiber}} \right)^2$$

- Fiber length, L_{fiber}=0.706mm
- Mean fiber diameter, D_{fiber}=16μm

2. Experimental data

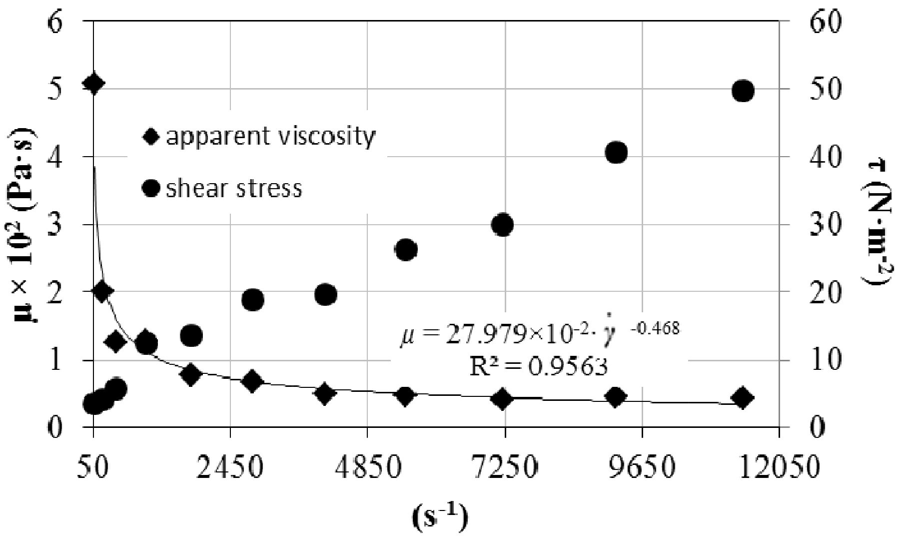


Figure 2 – Rheogram and apparent viscosity for pulp suspension of eucalyptus fibers (c=1.50% w/w).

Apparent viscosity of the pulp fiber suspension

$$\eta_{app} = K\left(\dot{\gamma}\right)^{n-1}$$

η_{app} – apparent viscosity

$\dot{\gamma}$ – shear rate

K – consistency coefficient

n – flow behaviour index

Table 2– Rheological data for the *Eucalyptus* pulp suspensions tested.

c (% w/w)	*K*	*n*
1.50	0.2798	0.532
2.50	10.721	0.247

3. Geometry

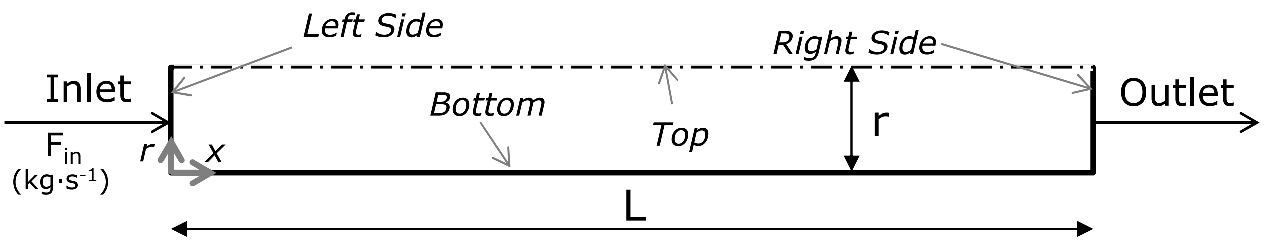


Figure 3 – Geometry and boundaries.

r = 0.0381 m

L = 1 m

Table 3 – Boundary conditions.

Location	Boundary Condition
Left Side	Periodic Boundary
Right Side	Periodic Boundary
Bottom	Wall
Top	Axis

The pulp flow is assumed as:

-Steady state (fully developed flow)

- *Isothermal*
- *Without mass transfer*
- *Incompressible*
- *2D flow with axial symmetry*
- *non-Newtonian fluid viscosity*

- **6 built-in LRN turbulence models were evaluated.**

ANSYS FLUENT

Built-in LRN turbulence models to be studied

- Lam-Bremhorst (LB)

- Abe-Kondoh-Nagano (AKN)

- Chang-Hsieh-Chen (CHC)

Lam, C.K.G.; Bremhorst, K. (1981) – *"A modified form of the k-ε model for predicting wall turbulence"* – Transactions of the ASME, 103(3):456-460
Abe, K.; Kondoh, T.; Nagano, Y. (1994) – *"A new turublence model for predicting fluid flow and heat transfer in separating and reattaching flows I: Flow field calculations"* – International Journal of Heat and Mass Transfer, 37(1):139-151
Chang, K.C.; Ssieh, W.D.; Chen, C.S: (1995) – *"A modified Low-Reynolds-Number turbulence model applicable to recirculating flow in pipe expansion"* – Journal of Fluids Engineering, 117(3):417-423
Hsieh, W.D.; Chang, K.C. (1996) – "*Calculation of wall heat transfer in pipe-expansion turbulent flows*" – International Journal of Heat and Mass Transfer, 39(18):3813-3822

General transport equation

$$\frac{1}{r}\left[\frac{\partial}{\partial x}(r\rho u\phi)+\frac{\partial}{\partial r}(r\rho v\phi)\right]=\frac{1}{r}\left[\frac{\partial}{\partial x}\left(r\Gamma_{\phi}\frac{\partial\phi}{\partial x}\right)+\frac{\partial}{\partial r}\left(r\Gamma_{\phi}\frac{\partial\phi}{\partial r}\right)\right]+S_{\phi}$$

Table 4 – Dependent variables ϕ, diffusibility term Γ_{ϕ} and source-term S_{ϕ} (Hsieh and Chang, 1996).

Equation	ϕ	Γ_{ϕ}	S_{ϕ}
Continuity	1	0	0
Momentum - axial	u	$\mu_{eff}=\mu+\mu_t$	$-\frac{\partial P}{\partial x}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial u}{\partial x}\right)+\frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial v}{\partial x}\right)$
Momentum - radial	v	$\mu_{eff}=\mu+\mu_t$	$-\frac{\partial P}{\partial r}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial u}{\partial r}\right)+\frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial v}{\partial r}\right)-2\mu_{eff}\frac{v}{r^2}$
Kinetic energy	k	$\mu+\mu_t/\sigma_k$	$G_k-\rho\varepsilon$
Dissipation rate	ε	$\mu+\mu_t/\sigma_\varepsilon$	$(C_{\varepsilon 1}f_1G_k-C_{\varepsilon 2}f_2\rho\varepsilon)\varepsilon/k$

$$G_k=\mu_t\left\{2\left[(\partial u/\partial x)^2-(\partial v/\partial r)^2-(v/r)^2\right]-(\partial v/\partial x-\partial u/\partial r)^2\right\};\qquad \mu_t=\rho C_\mu f_\mu k^2/\varepsilon$$

Cartesian coordinates
Steady state
2D geometry

Hsieh, W.D.; Chang, K.C. (1996) – *"Calculation of wall heat transfer in pipe-expansion turbulent flows"* - International Journal of Heat and Mass Transfer, 39(18):3813-3822

Table 5 – Damping functions.

Model	f_μ	f_1	f_2
LB	$\left(1-exp\left(-0.0165\,Re_k\right)\right)^2 \times \left(1+20.5/Re_t\right)$	$1+\left(0.05/f_\mu\right)^3$	$1-exp\left(-Re_t^2\right)$
AKN	$\left(1-exp\left(-Re_\varepsilon/14\right)\right)^2 \times \left(1+5\,exp\left(-\left(Re_t/200\right)^2\right)/Re_t^{3/4}\right)$	1.0	$\left(1-exp\left(-Re_\varepsilon/3.1\right)\right)^2 \times \left(1-0.3\,exp\left(-\left(Re_t/6.5\right)^2\right)\right)$
CHC	$\left(1-exp\left(-0.0215\,Re_k\right)\right)^2 \times \left(1+31.66/Re_t^{5/4}\right)$	1.0	$\left(1-0.01\,exp\left(-Re_t^2\right)\right) \times \left(1-exp\left(-0.0631\,Re_k\right)\right)$

$$Re_t = \frac{k^2}{\varepsilon\nu};\ Re_k = \frac{yk^{1/2}}{\nu};\ Re_\varepsilon = \frac{y\left(\mu\varepsilon/\rho\right)^{1/4}}{\nu}$$

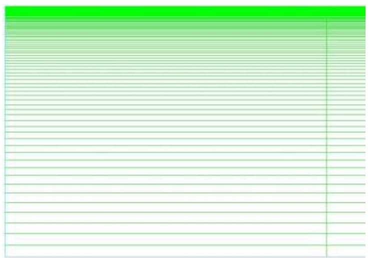
Convergence criterion = 1 ×10^{-5}
Water annulus and non-Newtonian fluid

Table 6 – Pressure drop values (Ansys Fluent UDF models).

c [% w/w]	U_{in} [m·s⁻¹]	$\Delta P/L_{exp.}$ [Pa·m⁻¹]	$\Delta P/L_{num}$ [Pa·m⁻¹]	δ [%]	$\Delta P/L_{num}$ [Pa·m⁻¹]	δ [%]	$\Delta P/L_{num}$ [Pa·m⁻¹]	δ [%]
1.50	4.49	829	1487	79	1605	94	360	57
	6.21	1289	3273	154	3145	144	3356	160
2.50	4.90	2299	2123	35	2178	38	2157	37
	5.55	2814	3040	73	2360	35	2335	33
			LB		AKN		CHC	

Not much improvement for this concentration – still CHC performs slightly better

CHC performs much better for higher consistencies



Non-uniform mesh
20×118 (*x* and *r)*

interval length ratio
R1.05

It was considered a **water annulus** with **thickness equal to fiber length**

Standard LRN turbulence models

- An **excellent agreement** was found between both the LRN turbulence **model implemented with the use of UDF** and **built-in model results.**

- A ***drag reduction*** can be observed in **all cases** when using **LRN turbulence models**.

- Preliminary results led us to conclude that the models **AB**, **AKN** and **CHC** showed a better fit to the experimental data.

- Models **LS** and **YS** did not converge for the higher concentration.

-Model **LB** showed larger deviations.

- CHC presents, in general, the best results (more notorious for the highest consistencies)

- To improve the numerical results, the **model damping function** f_μ can be **modified** taking into account the literature for **polymer solutions flows** or **particle suspensions flow**.

LRN turbulence models tested and modifications

- **Modification** of the **damping function** f_μ on the own-developed **LB**, **AKN** and **CHC** turbulence models in Ansys Fluent according the **information in literature for polymer solutions flow** and **particle suspensions flow** (uniform concentration distribution of the particles):

Malin *polymer solutions*

$$f_\mu = \left[1 - exp\left(-\frac{0.0165 * Re_k}{n^{1/4}}\right)\right]^2 \times \left(1 + \frac{20.5}{Re_t}\right)$$

n – flow behaviour index

Bartosik *particle suspensions flow*

$$f_\mu = 0.09\exp\left[-\frac{-3.4\left[1 + A_s{}^3 d^2(8 - 88A_s\, d)c_v{}^{0.5}\right]}{\left(1 + \frac{Re_t}{50}\right)^2}\right]$$

A_s – empirical constant
c_v – volume fraction of solids averaged in cross section
d – averaged solid particles diameter

$$Re_t = k^2/\varepsilon\upsilon \qquad Re_k = yk^{1/2}/\upsilon$$

- Test **different constant values** on the **new damping functions**.

Malin, M.R. (1997) – *"Turbulent pipe flow of power-law fluids"* – International Communications in Heat and Mass Transfer, 24(7):977-988
Bartosik, A. – *"Mathematical modelling of slurry flow with medium solid prticles"* – Mathematical Models and Methods in Modern Science, International Conference Mathematical Models and Methods in Modern Science, Spain, 10-12 December, 2011. ISBN 978-1-6-61804-055-8, pp.124-129.

New damping function tested

Malin damping function (LB model)

$$f_{\mu} = \left[1 - exp\left(-\frac{C_1 * Re_k}{n^{C_3}}\right)\right]^2 \times \left(1 + \frac{C_2}{Re_t}\right)$$

Table 7 – Different constant values on the Malin's damping function (Cotas et al. (2014a)).

	Case								
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
C_1	0.0165	**0.0100**	**0.0195**	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
C_2	20.5	20.5	20.5	**10.25**	**30.75**	20.5	20.5	20.5	20.5
C_3	0.25	0.25	0.25	0.25	0.25	**1.05**	**1.125**	**1.975**	**2.0**

Malin damping function

Preliminary results show that the **LB model modified** with the **Malin's damping function considering different constant values** does **not** induce better predictions (C_1 modification - Cotas et al. (2014b))

Cotas, C.; Garcia, F.; Ferreira, P.; Faia, P.; Asendrych, D. and Rasteiro, M.G. (2014a) – Chang-Hsieh-Chen low-Reynolds *k-ε* turbulence model *Adaptation to study the flow of concentrated pulp suspensions in pipes* – Oral presenteation WCCM XI-ECCM V-ECFD VI, 20-25 July 2014, Barcelona, Spain.

Cotas, C.; Silva, R.; Garcia, F.; Faia, P.; Asendrych, D. and Rasteiro, M.G. (2014b) – Application of different low-Reynolds *k-ε* turbulence models to model the flow of concentrated pulp suspensions in pipes – Proceedings of The 7th World Congress on Particle Technology (WCPT7), 19-22 May 2014, Beijing, China.

New damping function tested – Malin (*CHC model modified*)

Table 8 – Numerical pressure drop values – **CHC** model.

Similar to CHC

Case	***Modification***	***c* [% w/w]**	**U_b [m·s^{-1}]**	**Re_w**	**$\Delta P/L_{exp.}$ [Pa·m^{-1}]**	**$\Delta P/L_{num.}$ [Pa·m^{-1}]**	**δ [%]**
A1	CHC-Malin	1.50	4.49	340501	829	361	57
B1		1.50	6.21	470937	1289	3332	159
C1		2.50	4.90	371593	1579	2152	36
D1		2.50	5.55	402886	1754	2333	33
A4	C_2 = 10.25	1.50	4.49	340501	829	361	56
B8	C_3 = 1.975	1.50	6.21	470937	1289	420	67
C6	C_3 = 1.05	2.50	4.90	371593	1579	1582	0.2
D7	C_3 = 1.125	2.50	5.55	402886	1754	1774	1

Constants for the best results.

(in each case the other constants were kept the same as in malin

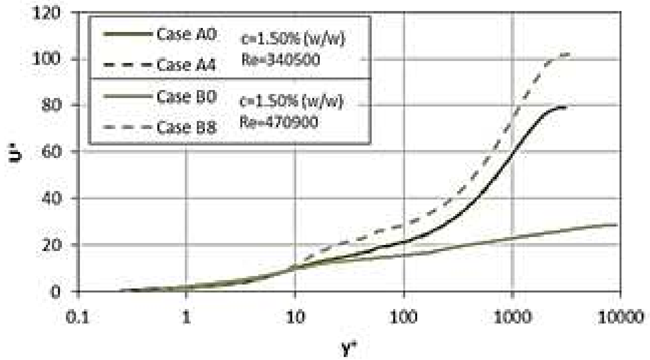
Good improvement for the high consistency

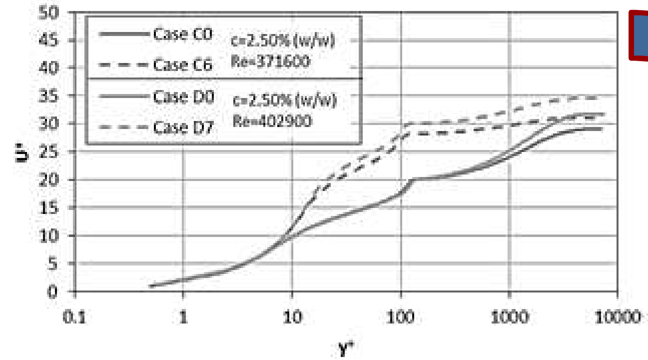
New damping function tested – Malin (*CHC model modified*)

es 0 - **CHC** model
hout modification

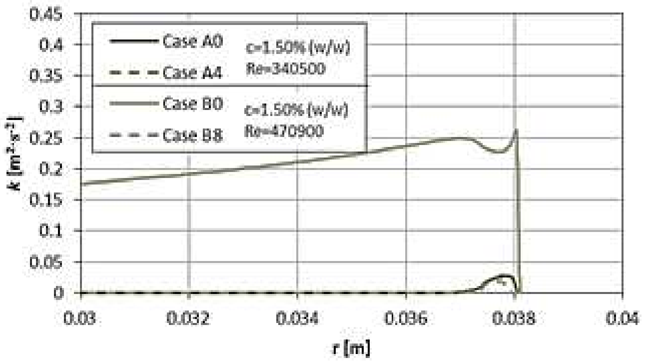
Table 9 – Numerical Results – **CHC** model.

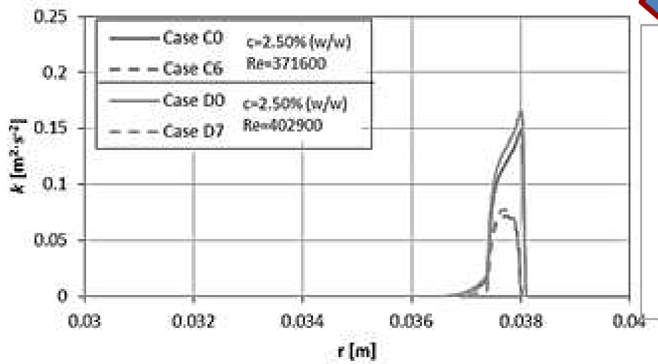
Dimensionless velocity





Turbulent kinetic energy





The differences in both the velocity and kinetic energy profiles are more notorious for the higher consistency

- Velocity increases
- K at the Wall decreases
- Pressure drop decreases

***New damping function tested* – Malin (*CHC model modified*)**

- The application of the damping function f_μ according to Malin **was not able** to improve the numerical results.

- The numerical results **can be improved** by **modifying the Malin damping function f_μ.**

- The **CHC** LRN turbulence model considering the **Malin damping function f_μ** with **C_3 modified** improves significantly the numerical results.

- The parameter **C_3** should be **closer but higher than 1.0** when the pulp consistency is equal to **2.50% (w/w)**.

- The damping function "optimized" **reduces significantly** the **turbulence** and the **pressure drop is lower** than that obtained with the Malin damping function.

New damping function tested – Malin (AKN model modified)

Table 10 – Numerical pressure drop values – **AKN** model.

Similar to AKN

Case	*Modification*	*c* [% w/w]	U_b [m·s^{-1}]	Re_w	$\Delta P/L_{exp.}$ [Pa·m^{-1}]	$\Delta P/L_{num.}$ [Pa·m^{-1}]	δ [%]
A1	AKN-Malin	1.50	4.49	340501	829	1698	105
B1		1.50	6.21	470937	1289	3240	151
C1		2.50	4.90	371593	1579	2205	40
D1		2.50	5.55	402886	1754	2380	36
A2	C_1 = 0.0100	1.50	4.49	340501	829	1147	38
B2	C_1 = 0.0100	1.50	6.21	470937	1289	2821	119
C9	C_3 = 2.0	2.50	4.90	371593	1579	1986	26
D9	C_3 = 2.0	2.50	5.55	402886	1754	2190	25

Constants for the best results.
(in each case the other constants were kept the same as in Malin

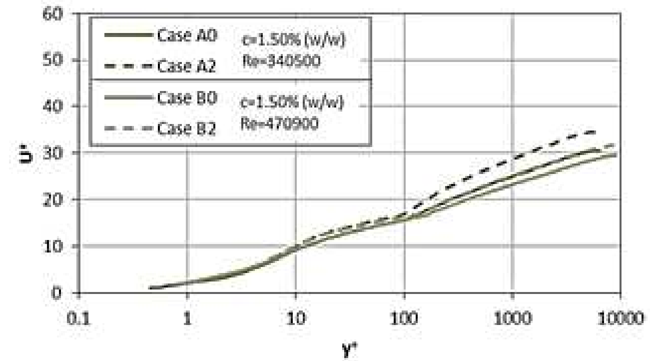
Slight improvement

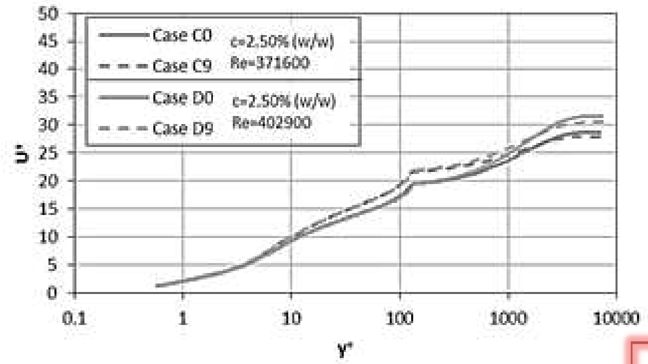
New damping function tested – Malin (*AKN model modified*)

es 0 - **AKN** model
hout modification

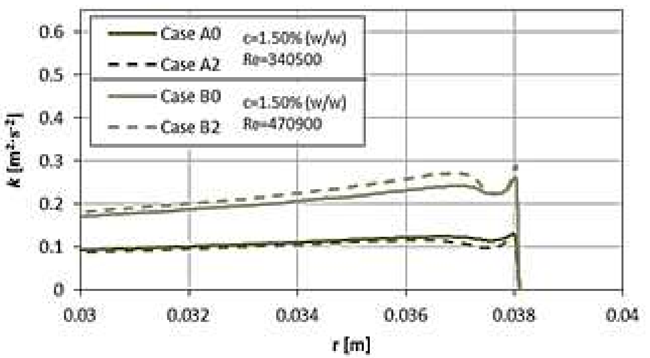
Table 11 – Numerical Results – **AKN** model.

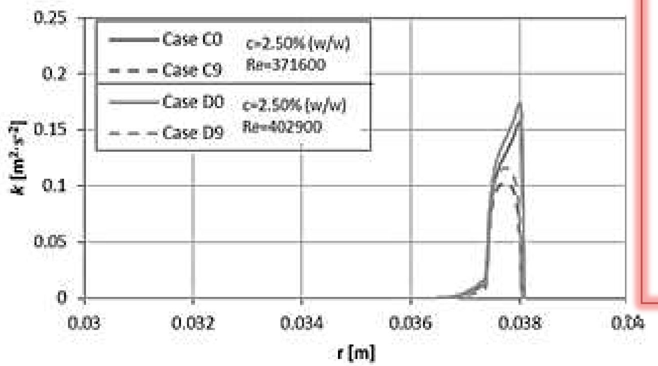
Dimensionless velocity





Turbulent kinetic energy





- The influence of altering the constants in the Malin damping function when using the AKN model are not as importante as in the case of the CHC model
- The tendencies are the same as observed with the CHC model.

***New damping function tested* – Malin (*AKN model modified*)**

- The numerical results **were not improved** by applying the damping function f_{μ} according to Malin.

- The numerical results, mainly when c=2.50% (w/w), **can be improved** by **modifying the Malin damping function f_{μ}.**

- The parameter C_3 should be modified for the higher consistency cases, but for the lower consistency cases the parameter C_1 influences strongly the numerical results.

- The damping function "optimized" has a strong effect on the turbulence.

New damping function tested

Bartosik damping function

$$f_\mu = 0.09\exp\left[-\frac{-3.4\left[1 + {A_s}^3 d^2 (8 - 88 A_s\, d) {c_v}^{0.5}\right]}{\left(1 + \frac{Re_t}{50}\right)^2}\right]$$

Table 12 – Different parameters on the Bartosik's damping function.

		Case 10		
c **[% w/w]**	U_{in} **[m·s⁻¹]**	A_s	***d* [mm]**	c_v
1.50	4.49	100	0.016	1.50
	6.21			1.50
2.50	4.90			2.50
	5.55			2.50

New tests should be performed to test the influence of A_s and *d (fiber dimensional parameter)* on the numerical results.

New damping function tested – Bartosik

Good improvement mainly for the low consistencies

Table 13 – Numerical pressure drop values.

Case	*Modification*	*c* [% w/w]	U_b [m·s^{-1}]	Re_w	$\Delta P/L_{exp.}$ [Pa·m^{-1}]	$\Delta P/L_{num.}$ [Pa·m^{-1}]	δ [%]
A10	CHC-Bartosik	1.50	4.49	340501	829	1134	37
B10		1.50	6.21	470937	1289	1957	52
C10		2.50	4.90	371593	1579	1966	25
D10		2.50	5.55	402886	1754	2109	20
A10	AKN-Bartosik	1.50	4.49	340501	829	1005	21
B10		1.50	6.21	470937	1289	1934	50
C10		2.50	4.90	371593	1579	1957	24
D10		2.50	5.55	402886	1754	2100	20

- The Bartosik damping function f_μ has a strong impact on the numerical pressure drop.

- The Bartosik damping function can be modified to get better approaches to the numerical pressure drop, namely, the parameter A_s and modify also *d* (fiber dimension) to be the fiber aspect-ratio or fiber length.

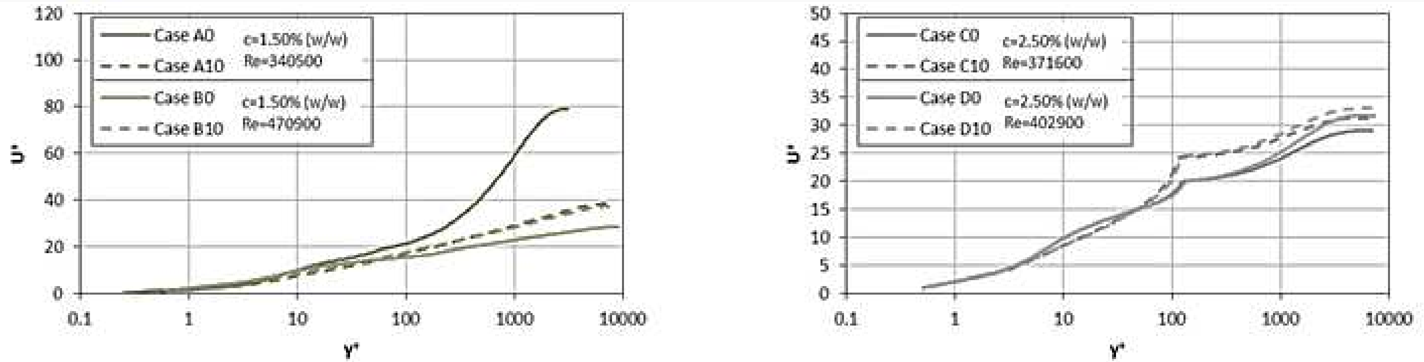
6. Numerical results

New damping function tested – Bartosik

Cases 0 - **CHC** model without modification

Table 14 – Numerical Results – **CHC-Bartosik** model.

Dimensionless velocity



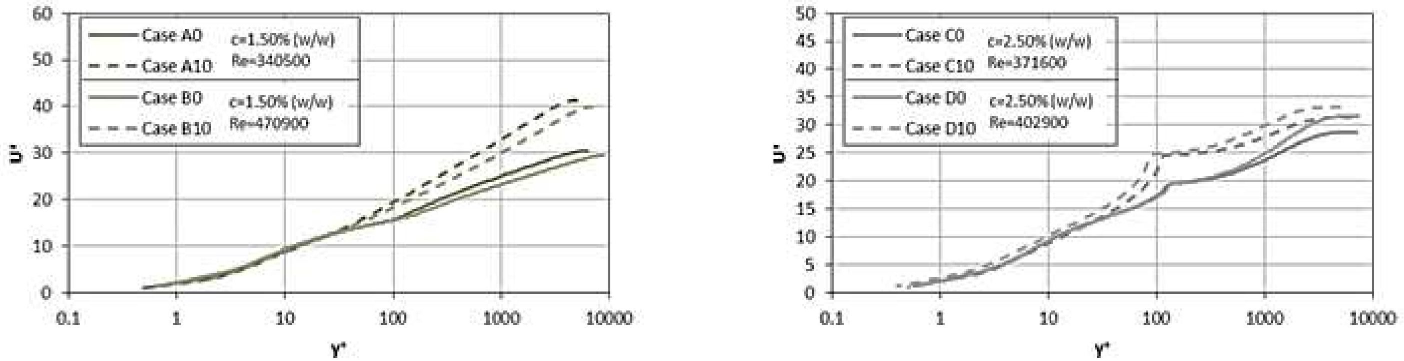
- The velocity profile is not much affected by the introduction of the Bartosik damping function (some decrease for the lower consistency)

New damping function tested **– Bartosik**

Cases 0 - **AKN** model without modification

Table 15 – Numerical Results – **AKN-Bartosik** model.

Dimensionless velocity



- The velocity profile is not much affected by the introduction of the Bartosik damping function
- Turbulence increases slightly using the Bartosik damping function mainly.
- These trends are in-line with what was observed for the CHC model.

New damping function tested **– Bartosik**

- The application of the damping function f_μ according to Bartosik **was able** to improve the numerical results for all the cases tested.

- The numerical results for the lower consistency cases **were improved significantly** by **modifying the damping function** $\boldsymbol{f_\mu}$ according to Bartosik.

- The damping function slightly modified the **dimensionless velocity profiles, with the CHC model lower velocities were obtained leading to lower pressure drop values**.

- Consider the **Bartosik damping function** on the **AKN** or **CHC** LRN turbulence models leads to **similar values of pressure drop**, t**urbulence** and **dimensionless velocity profiles for the two models**.

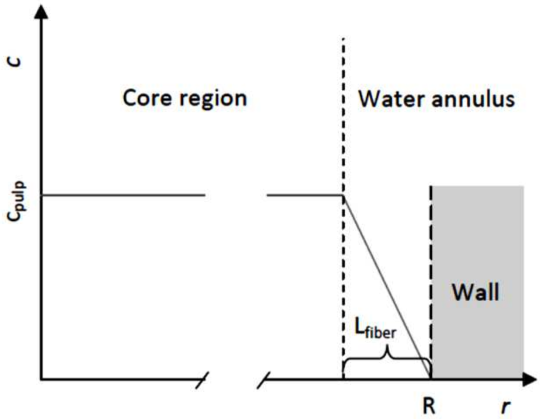


Figure 4 – Consistency profile (adapted from Dong et al. (2003) and Olson (1996)).

Pulp's consistency – Water annulus

$$c(r) = -c_{pulp}\left[r - \left(R - L_{fiber}\right)\right] / L_{fiber} + c_{pulp}$$

Experimental data, pulp consistencies (% (w/w)):
1.50
1.80
2.50
2.90
3.20
3.50

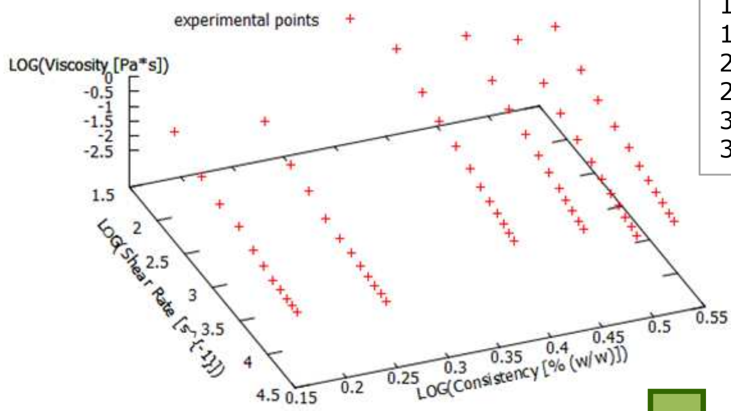
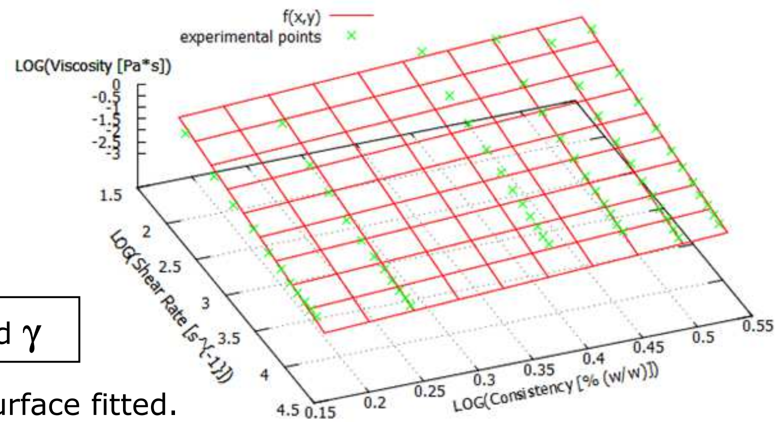


Figure 5 – Experimental data representation.



Apparent viscosity of the pulp fiber suspension

$$\eta_{app} = \frac{c^{a1}}{\dot{\gamma}^{a0}} \cdot a2$$

Dependence on c and γ

Figure 6 – Surface fitted.

Dong, S.; Feng, X.; Salcudean, M.; Gartshore, I. (2003) – "Concentration of pulp fibers in 3D turbulent channel flow" – International Journal of Multiphase Flow, 29(1):1-21.
Olson, J.S. (1996) – The effect of fiber length on passage through narrow apertures. PhD thesis, University of British Columbia.

7. Viscosity *new expression* *(dependence on concentration in the water annulus)*

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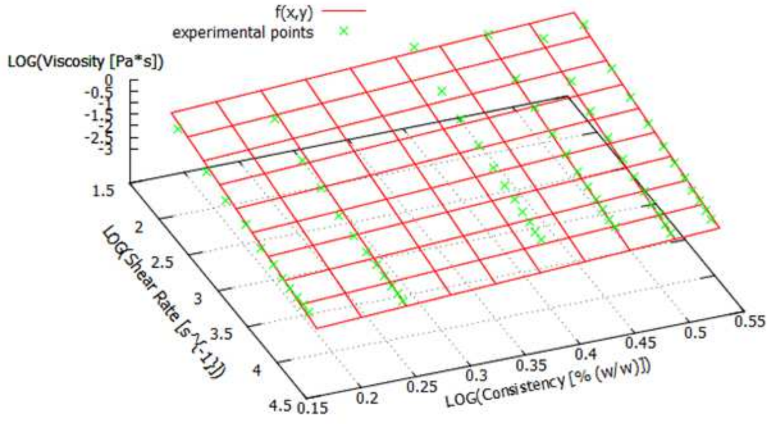


Eucalyptus pulp

- consistency = 1.50, 1.80, 2.50, 2.90, 3.20 and 3.50% (w/w)

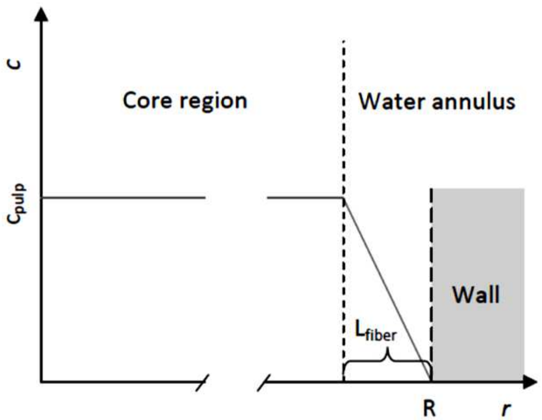
- L_{fiber} = 0.706 mm

$$\eta_{app} = \frac{c^{a1}}{\dot{\gamma}^{a0}} \cdot a2$$

a0 = 0.683

a1 = 2,40

a2 $= 10^{-0.226}$



$$c(r) = \begin{cases} c_{pulp}\,, & core\ region \\ -c_{pulp}\left[r-\left(R-L_{fiber}\right)\right]/\,L_{fiber} + c_{pulp}\,, & water\ annulus \end{cases}$$

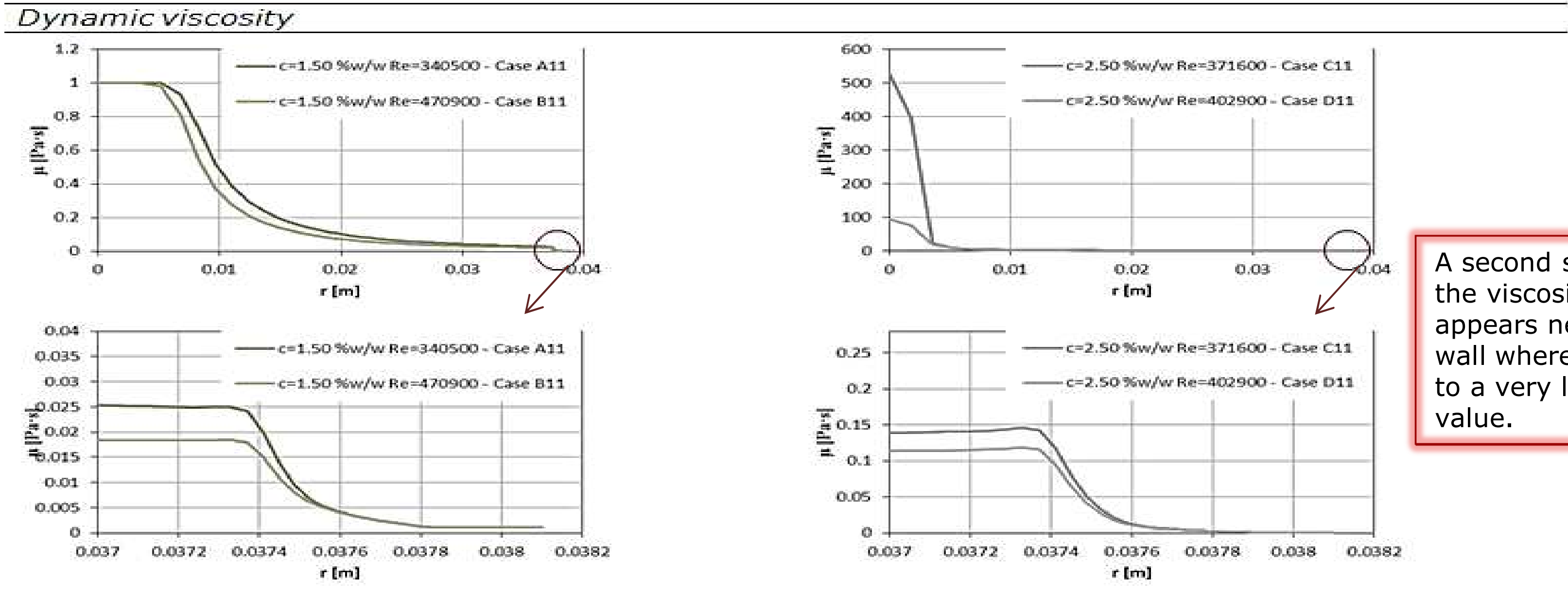
7. Viscosity *new expression*
(dependence on concentration in the water annulus)

Table 16 – Numerical pressure drop values – **AKN** model.

Case	***c* [% w/w]**	**U_b [m·s^{-1}]**	**Re_w**	**$\Delta P/L_{exp.}$ [Pa·m^{-1}]**	**$\Delta P/L_{num.}$ [Pa·m^{-1}]**	**δ [%]**
A11	1.50	4.49	340501	829	567	32
B11	1.50	6.21	470937	1289	665	48
C11	2.50	4.90	371593	1579	1639	4
D11	2.50	5.55	402886	1754	1785	2

Good approximation mainly for the high consistency

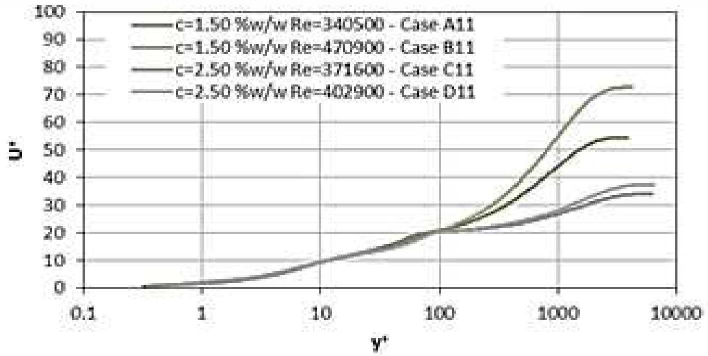
Table 17 – Viscosity profiles – **AKN** model.



A second step on the viscosity profile appears near the wall where it tends to a very low value.

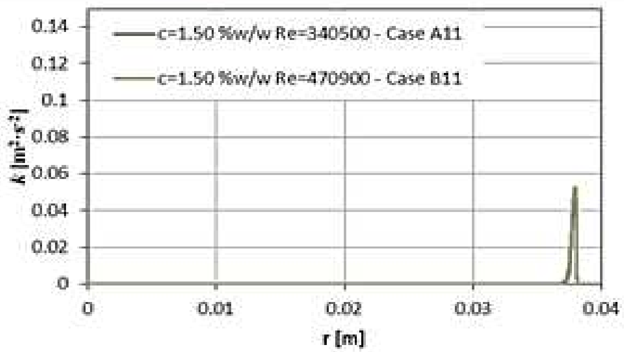
Table 18 – Numerical Results – **AKN** model.

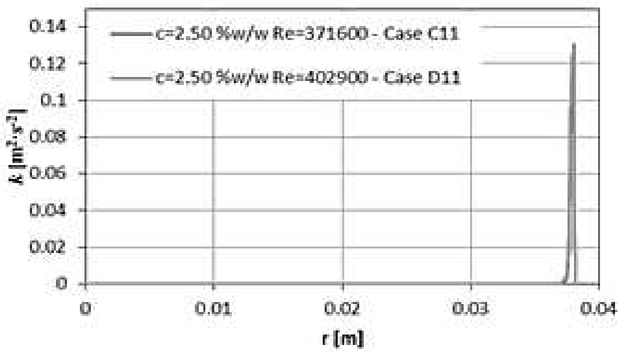
Dimensionless velocity



Both the velocity and kinetic energy profiles follow the usual trend.

Turbulent kinetic energy





7. Viscosity *new expression*
(dependence on concentration in the water annulus)

- Consider **the presence of fibers in the water annulus** is **more realistic** from the physical point of view and this can be related with the **better approach to the experimental data**.

- The ***drag reduction* effect** is reproduced with this **new viscosity expression** and **standard AKN** turbulence model.

- The **velocity profiles follow the tendency reported by Jäsberg (2007)**.

- The **turbulent kinetic energy is strongly reduced near the wall** when comparing with the results considering the standard AKN model and the water viscosity in the water annulus.

Jäsberg, A. (2007) – *"Flow Behavior of Fibre suspensions in Straight Pipes: New Experimental Techniques and Multiphase Modeling"*. PhD Dissertation, Faculty of Mathematics and Science of the University of Jyväskylä, Jyväskylä, Finland

- The **LB**, **AKN** and **CHC** LRN turbulence models can be applied successfully to study the turbulent pipe flow of pulp suspensions.

- These three models **can be modified taking into account** the cases from literature for the **power-law** and **particles turbulent flow** simulation, namely, modifying the **damping function** f_{μ}.

- **Significant improvement** of the numerical results can be obtained **modifying the Malin damping function**.

- **Modify** the AKN and CHC LRN turbulence models with the damping function according to **Bartosik** leads to a **better approach** to the experimental results.

- The **near wall effects** are **quite important** for the pulp flow and the turbulence model should deal correctly with them.

- The **introduction** of **the dynamic viscosity** as **a function of shear** rate and **fiber consistency** and, also, the **fiber consistency** (in the very thin layer at the pipe wall surrounding the flow core) **as a function of pipe radius** leads to **good predictions** of the experimental data.

- The **dimensionless velocity profiles are higher for the lower consistency cases** and a **peculiar S-shaped could be observed**.

- Study the modification of the Bartosik damping function:
  - different values for the parameter A_s
  - replace *d* by fiber length and fiber aspect ratio
  - test a new damping function considering the yield stress
- Test the new expression for viscosity (function of shear rate and consistency) and the existence of fibers in the water annulus in the CHC and AB LRN turbulence models.
- Analyze the influence of the “water annulus” thickness on the numerical results.
- Modify the AKN and CHC LRN turbulence models – new viscosity expression and existence of fibers in the water annulus – with the damping functions of Bartosik and Malin.
- Conduct rheological tests to try to obtain information for lower shear rates.

Thank you for your attention...

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New advances in modelling of fibre suspension flow using a pseudo-homogeneous approach

COST ACTION FP1005
(7th Joint MC/WG Meeting)

3-5 June 2014, Stockholm, Sweden

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