CHAPTER 7

SIMULATION WITH INDUSTRIAL DATA

7.1 INDUSTRY PROFILE

One of the objectives of this study is to collect the data from a laboratory/industry and simulate the same to obtain the numerical results for pulp washing models. To achieve this, data from a renowned wood and agro-based paper plants in India, M/s Satia Industries Ltd. (formerly known as Satia Paper Mills Ltd.) Muktsar, Punjab (Figure 7.1) is collected for simulation. Owing to its noticeable market share and accessibility of the experimental data, this production unit was selected for the study. The company started its operations in August 1984 and produces paper using non-conventional raw materials such as wood chips, wheat straw, wastepaper, veneer waste, sarkanda, etc. The plant is having a production capacity of 1,05,000 million tons per annum (MTPA)*.

Figure 7.1 Satia Paper Mills, Ltd.

To economize the consumption of chemicals and to achieve the prescribed standards of effluent discharge, the company has set up a chemical recovery plant that helps in reducing the environmental load.

* Source: www.satiagroup.com

7.2 ANALYSIS OF INDUSTRIAL DATA

The industrial data is collected from this unit based on the wheat straw as a raw material. Besides, the value of parameters is collected from a brown stock washer (Figure 7.2) at the 4th stage of the pulp washing process.

Figure 7.2 Brown stock washer.

The purpose of collecting the industrial data from this paper mill is to study and check the applicability of the proposed technique in solving the mathematical models of pulp washing. The outcome of this study can be helpful in reducing the environmental load as well as improving the efficiency of the industry. The detailed raw data for experimental values of the brown stock washer is given in Table 7.1.

Further, important industrial parameters such as bed porosity, fiber consistency, fiber porosity, interstitial velocity, and axial dispersion coefficient are required to analyze the mathematical models. In the present study, these parameters are calculated using the expressions given by Kukreja (1996). The detail of the same is described in Table 7.2.

Table 7.1 Experimental data collected from the paper mill

Parameter	**Range**	**Parameter**	**Range**
Dissolved solid inside the vat (Xi) (%)	10-11	Amount of liquor in discharged pulp (L_d) (%)	14-15(solid)
Density of fibre (kg/m^3)	1.2-1.3	Shower liquor concentration (Cs) (%)	9-10
Inlet vat consistency of pulp (Cyi) (%)	1.2 - 1.5	Radius of washer (m)	1.825
Discharged consistency of pulp (Cyd) (%)	14-15	Length of lab washer	11m
Density of water (ρ) (kg/m^3)	1000	Pulp kappa number	10-11
Specific surface of fibre (a) (cm^2/cm^3)	1.3	PH value of vat liquor	11.5-12
Pressure drop (ΔP) (pascal)	20000	Concentration of solute inside the vat(kg/m^3) (%)	8-10
Viscosity of liquor (μ) (kg/ms)	11.0-12.0	Dilution factor	2.5-3.0
Density of wash water (kg/m^3)	1.2-1.4	Variable cake thickness (L) (m)	0.020-0.025
Speed of drum (RPM)	2-2.5	Filtrate flow rate (m^3/s)	0.0333
Angle of submergence (∅)(^{o})	60-65	Fibre production rate (FPR)(kg/s)	10TPH 2.5199 kg/s
Fractional submergence ($\emptyset/2\pi$)(%)	16-18	-	-

Table 7.2 Expression used to calculate data from Kukreja (1996).

Parameter	**Expression**
Bed Porosity	$\dfrac{\rho_f(1-C_y)}{\rho Cy+\rho_f(1-C_y)}$
Fibre consistency	$\varepsilon=1-6.8\times10^{-4}C_F$ $C_F=(1-\varepsilon)/0.00068$
Fibre porosity	$\beta=1-1.75\times10^{-3}C_F$
Interstitial velocity	$u=\dfrac{K\Delta P}{\mu L\beta}$ where $K=\left[3.5a^2(1-\varepsilon)^{3/2}\left\{1+57(1-\varepsilon)^3\right\}\right]^{-1}$
Axial dispersion coefficient	$D_L=3.99\times10^{-3}u$

Using the relations in Table 7.2, the range of parameters mentioned above are calculated with the help of raw data available in Table 7.1 and these values are expressed in Table 7.3.

Table 7.3 Calculated data for simulation.

Parameter	**Range**
Interstitial velocity (u) (m/s)	5.56×10^{-4}-9.98×10^{-4}
Fibre consistency (C_F) (kg/m^3)	55.882-86.764
Particle porosity (β)(Dimensionless)	0.848-0.902
Porosity of cake (ε) (Dimensionless)	0.941-0.962
Axial dispersion coefficient (D_L)(m^2/s)	2.218×10^{-6}-3.982×10^{-6}

One of the main tasks of this study is to simulate the model using the experimental data of a paper mill. The nonlinear models are considered for this purpose because these models are more realistic whereas the assumptions are simplified in the linear models.

7.3 RESULTS FROM NONLINEAR MODEL-1

The nonlinear model is solved using the QHCM and the collected data from the paper mill is used for the simulation of numerical results. Besides this, the effect of some important parameters is also discussed in this part.

7.3.1 Effect of *Pe* on the Concentration Profile

The model is solved by taking different values of *Pe*=3,6,10,20,25 and the output results in terms of concentration are presented in the form of a breakthrough curve (Figure 7.3). It can be seen from the figure that the concentration of solute at the exit level approaches zero smoothly. The exit solute concentration for a small value of *Pe* takes much time to come out from the pores of the particle. In this state, the value of added fluid quickly mixes with the pulp and the same amount of black liquor is discharged from the pulp. It is also noticed that when the value of *Pe* is increased, the washing time decreases steeply. This is a state when the original contents from the bed are enforced to get out as a piston-like style when the displacing fluid is introduced.

In an ideal situation, the soluble impurities lying within the pulp washing bed cannot be properly removed. Although the medium range of *Pe* is preferred because more time is taken by the residing solute to wash out and concentration profiles are slowly converging to zero, this is a case of quite an acceptability. It is observed from Figure 7.3 that the target of efficient washing is achieved for *Pe* between 10 and 20.

7.3.2 Effect of Porosity on the Concentration Profile

The bed porosity is also an essential factor in the washing procedure. The effect of porosity (e) on the concentration of solute at the exit level is described in Figure 7.4. The concentration profile at the exit level for the range of porosity between 0.941-0.961 (mentioned in Table 7.3) is calculated. It is noticed that this range of porosity has not much effect on concentration profile.

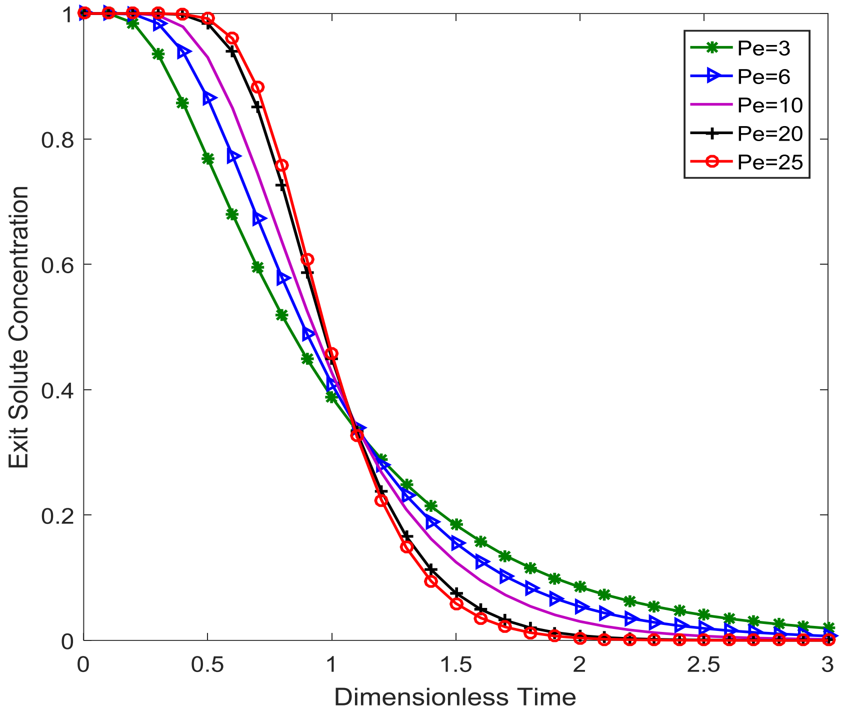

Figure 7.3 Effect of *Pe for* c_0 =0.08, A=0.01195, B=2.708, c_s=0.01, C_F=55.88 and e=0.962

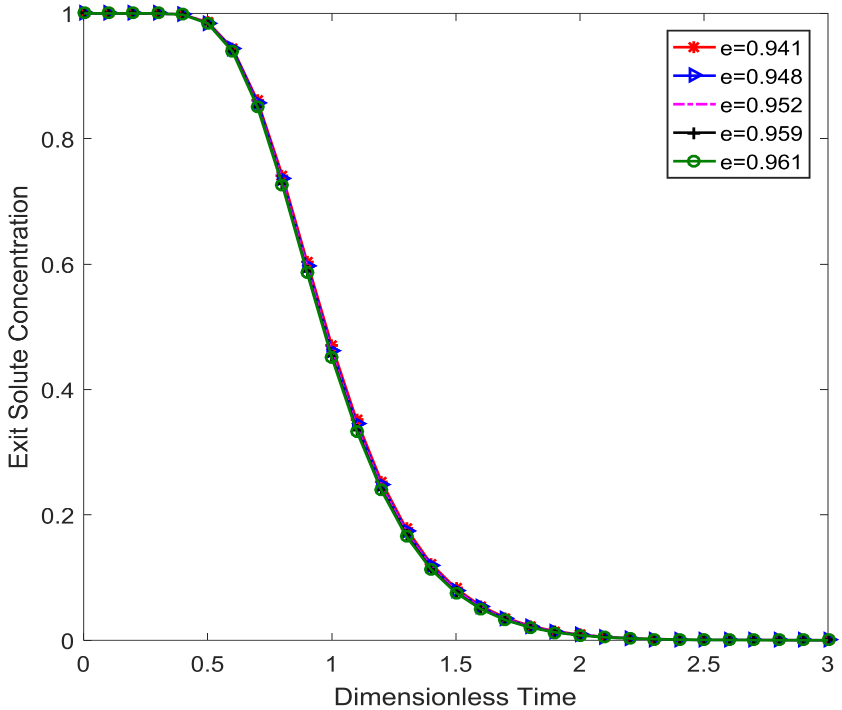

Figure 7.4 Effect of porosity (*e*) for c_0 =0.08, A=0.01195, B=2.708, c_s=0.01, C_F=55.88

7.3.3 Effect of Fiber Consistency (C_F)

The fiber consistency is also a very important parameter in the washing process. The output results of exit solute concentration profiles for different values of fiber consistency are presented in Figure 7.5. The results are obtained for the range of fiber consistency between 55.88 - 81.52 as mentioned in Table 7.3. It is seen from Figure 7.5 that the concentration of solute is not much affected by this range of fiber consistency.

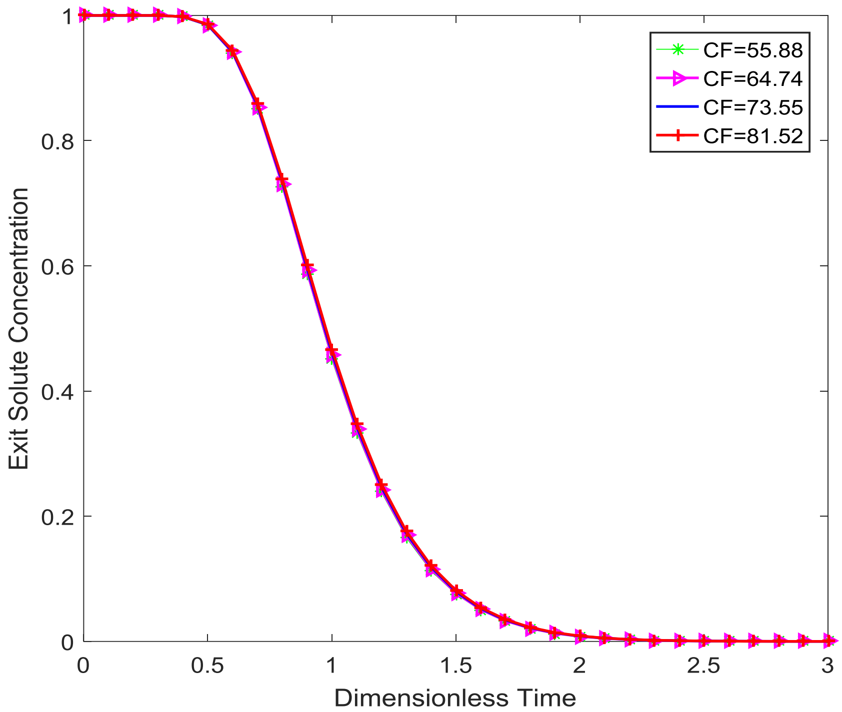

Figure 7.5 Effect of fiber consistency for c_0 =0.08, A=0.01195, B=2.708, c_s=0.01, e=0.961

7.4 RESULTS FROM NONLINEAR MODEL-2

The nonlinear model -2 discussed in the last chapter is solved with the help of the proposed method, i.e., QHCM. The numerical results derived for the concentration of solute at the exit level are expressed with the breakthrough curve. The numerical results for exit solute concentration are derived using experimental data from the paper mill. The results obtained for different values of parameters are mentioned in the subsequent paragraphs.

7.4.1 Effect of Peclet number (*Pe)* on the Concentration Profile

In Figure 7.6, the solution profiles for exit solute concentration for different range of *Pe* lying from 2 to 20 is shown. In the case when Pe takes a value of more than 10, the exit solute concentration is more peaked with more rate of convergence. When the value of *Pe* is small, slow convergence of the concentration profiles of exit solute is seen in figure. It is observed that better washing results are achieved when the value of *Pe* lies between 10 to 20.

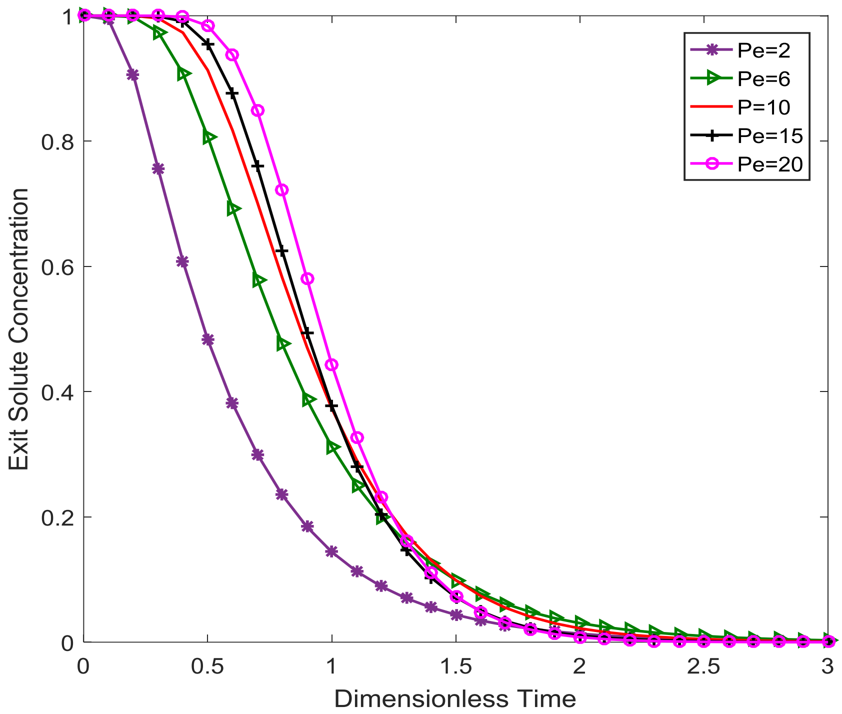

Figure 7.6 Effect of *Pe* for c_0 =0.08, A=0.01195, B=2.708, c_s=0.01, C_F=86.76

7.4.2 Effect of Bed Porosity (e) on the Concentration Profile

The bed porosity is also an essential factor in the washing procedure. The effect of porosity on the concentration of solute at the exit level is described in Figure 7.7. The concentration profile at the exit level for the range of porosity between 0.941 - 0.961 (mentioned in Table 7.3) is calculated. It is noticed that for this model this range of porosity has little effect on the concentration profile.

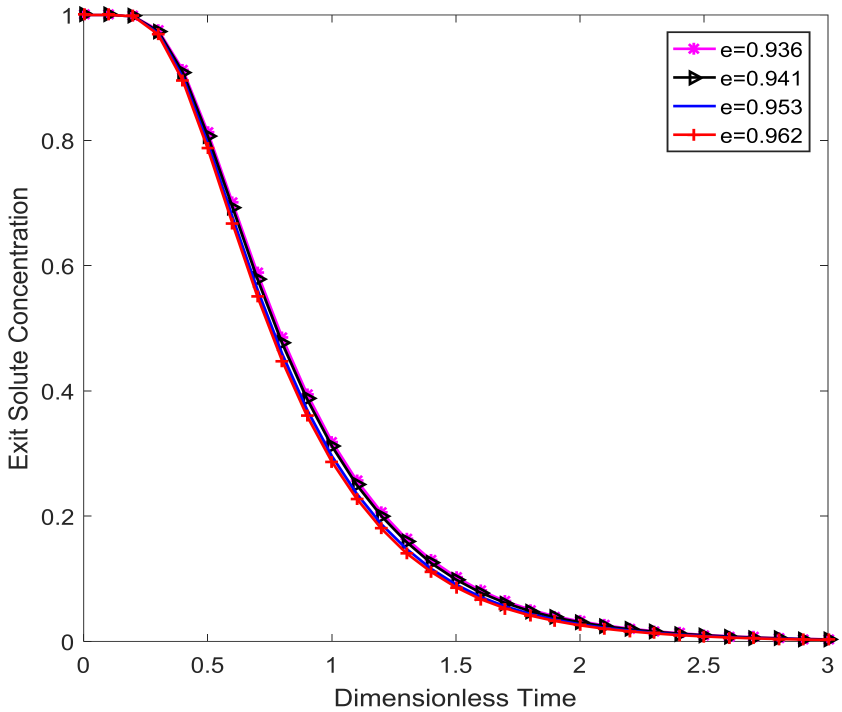

Figure 7.7 Effect of porosity for c_0 =0.08, A=0.01195, B=2.708, c_s=0.01, C_F=86.76

7.5 SUMMARY

The industrial data is collected from a brown stock washer (unit of a paper mill) based on the wheat straw as a raw material at the 4^{th} stage of the pulp washing process. The data required for simulation is calculated from the raw data received from this unit. It was found that efficient washing is achieved for Pe between 10 and 20. Besides, the range of porosity 0.941-0.961 has not much effect on the concentration profile. The concentration of solute is not much affected by this range of fiber consistency between 55.88 - 81.52.