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Chemistry

OPTIMIZATION OF DELIGNIFICATION PROCESS PULP REFINERY WITH ANSYS FLUENT CFD MODELING 19.2

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ABSTRACT The delignification process in the study, obtained standard Kappa (lignin) pulp levels (19-22) based on production data on 2 September 2019 which approached a maximum capacity of 4220.6 ADT / D, at a pulp mill that had a tank capacity of 5140 m³ and high 68,295 m2 by optimizing White Liquor (NaOH) dosages of 18, 19, 20, 21, 22 g / l and temperatures 141, 142, 143, 144, 145 0C based on the control parameters of the pulp mill cooking control. The research modeled using CFD Ansys Fluent 19.2 can compare actual field data which analyzes the expected lignin results at compatible NaOH concentrations and temperatures. In addition, from the research obtained the Contour of Lignin Mass, NaOH, Na-Lignate, H2O, Reaction Kinetics Rate, Density Contour and Mass Fraction of Reactants and Products Against Digester Height.

KEYWORDS : Delignification, Kappa, Digester, Ansys Fluent Modeling

INTRODUCTION

The study was carried out on an industrial scale, the pulp refinery having a production capacity of 5140 m³ / D digester, based on actual data that had been carried out with 4220.6 ADT / D pulp production obtained by lignin, temperature and NaOH concentration. Then the results of the actual qualification lignin data on the digested pulp obtained from the electrical resistance tomography (ERT) were validated with the 2-dimensional ansys fluent modeling 19.2. Getting the expected lignin value according to operational standards, this study varied the NaOH concentration and temperature so as to optimize the dose of NaOH use. Previous research of Liquor Flow in a Kraft Batch Digester Model, modeling with 2-dimensional CFD and digester equipped with electric resistance tomography (ERT) to evaluate the uniformity of zones created by the liquid phase and data used to rationalize measurements of pulp uniformity available in the literature and to provide input computational models that calculate the spatial distribution of reactions in [1]. The Nonlinear inferential multi-rate control of Kappa number at multiple locations in a continuous pulp digester, shows a research scale digester where calculating Kappa values using the model predictive control (MPC) nonlinear process, is then developed using the Kalman filter from a batch digester model to control the Kappa number is expected, by making veesel which have cooking mcc and emcc zones in each zone. Then give a White Liquor injection to manipulate the level of delignification and validate the data by modeling the process using a CFD computerized process. [2].

MATERIALS AND METHODS

Materials

The pulp refinery industry using *Manghium acacia* wood raw material which has the characteristics of Moisture Content 43.47%, Density 273.1 Kg / , PH 5.4 and Skin Content 0.47%, in addition the average wood content consists of Lignin 21-25%, Extractive 2-8%, Carbohydrates 67 -77% composed of Cellulose and Hemicellulose (which is 60% Fiber and 40% Humidity [3]. Based on the Design Digester used, can be seen in Table 1 and for Data Data Control parameters of the digester cooking can be seen in Table 2.

Tabel1. Data design digester [4].

Data Desain	Desain Standar
Medium	Chips, Black Liquor and white Liquor
Medium Density	1050 Kg/m³
Tekanan Desain	7.5 bar (Top Part)
Temperatur Aktual	200 0C
Temperatur Desain	215 0C
Kapasitas Tangki	5140 m³
Tebal Jaket Tinggi Tangki	100 mm 68,295 m2

Tabel2. Data Paremeter kontrol cooking [4].

Keterangan	Unit	Nilai
production	adt/d blowline	4200
production Digester	adt/h	175
CM Filling Factor	%	90
Yield	%	53
Chip Density	kg/m3	170
Chip Moisture	%	45
WL charge, Total	% EA as NaOH	16,7
WL flow to digester & HP feeder	l/s	55
WL charge to digester	% of Total	9,4
Chip Meter Speed	rpm	10,8
Temp top ext	℃	144,9
Temp bottom ext	℃	151,2
temp WL top		140,9
C2 laju alir chip	l/s	654
Kecepatan Chip	rpm	10,8

Variable values that will be tested such as the concentration of NaOH at temperatures during cooking in the digester to produce pulp amounted to 4220.6 ADT / D and kappa number 20.77-21.54.

CASE STUDY

In this study, the independent variables used were temperature of 141oC, 142oC, 143oC, 144oC, and 145oC and the concentration of NaOH with variations of 18 g / L, 19 g / L, 20 g / L, 21 g / L, and 22 g / L. The fixed variable used is the lignin mass flow rate of 7167.1 tons / d and also NaOH of 10249.2 m3 / d supplied into the digester analyzed using CFD ANSYS Fluent 19.2 to simulate the delignification process in the digester based on actual field data on the digester Table 3.

Tabel 3. Data on Actual Analysis Results 2 September 2019 [4].

C NaOH (g/L)	T (C)	Kadar Lignin (%)
18	143	19,6
18	144	22,4
19	144	22,1
20	145	19,1
21	144	20,6
22	145	20,8

Research using ANSYS FLUENT 19.2 to simulate the process of delignification in degesters, using the equation of conservation of momentum inertia (non-acceleration), can be seen in the equation (1) (5) .

$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla.(\rho\vec{v}\,\vec{v}) = -\nabla p + \nabla.(\bar{\tau}) + \rho\vec{g} + \vec{F} \quad (1)$$

Where is the static pressure, is the voltage tensor, tensor voltage is obtained [21].

$$\bar{\tau} = \mu\left[(\nabla\bar{v} + \nabla\bar{v}^{T}) - \frac{2}{3}\nabla.\bar{v}\, I\right] \quad (2)$$

Where is the molecular viscosity, I is the tensor unit, and is the volume dilution effect. The equation for mass conservation, or continuity equation, can be seen in the equation (3) [5].

$$\frac{\partial\rho}{\partial t} + \nabla.(\rho\bar{v}) = S_m \quad (3)$$

ANSYS Fluent 19.2 Solves has an energy equation which is the transfer of energy due to conduction, diffusion, and viscosity of dissipation, each included in the heat of a chemical reaction, and a volumetric heat source where (4) [5].

$$E = h - \frac{p}{\rho} + \frac{v^2}{2} \quad (4)$$

and for incompressible flow (5)

$$h = \sum_j Y_j h_j + \frac{p}{\rho} \quad (5)$$

The kinetic energy of turbulence, and its dissipation rate, is obtained from the transport equation of the standard k-ε model.

The results of the study used the ANSYS Fluent 19.2 CFD software application to simulate the delignification process in the digester. The stages used are described, namely the making of geometry, meshing, setting the equations of the model and the reactions used. Furthermore, it displays the results of the modeling consisting of changes in contours that occur at each point that either form the flow pattern of speed, temperature or concentration of each composition. Fixed variable lignin mass flow rate of 7167.1 tons / d and also NaOH of 10249.2 m3 / d while the independent variables are lignin concentration and temperature, obtained by Validation of Simulation Results Data to Actual Data we can see in the figure I.

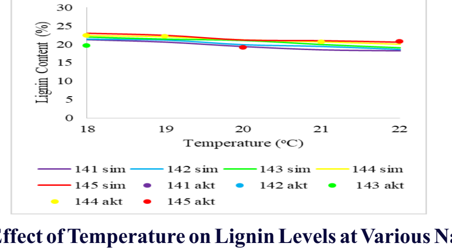

Figure 1. Effect of Temperature on Lignin Levels at Various NaOH Concentrations (Legend Points = Experiments; Lines = CFD Simulation)

Effect of Temperature on Lignin Levels on Various NaOH Concentrations (Legend Points = Experiments; Lines = CFD Simulation) Effect of Temperature on Lignin Levels at Various Concentrations This is caused by the kinetics of the reaction which is faster along with temperature, which results in the product being produced also faster. Data obtained from the simulation results are used to analyze several aspects. This aspect includes the mass fraction of each change, changes in temperature and also the distribution, velocity profile, and can also be seen streamlined from the vector velocity that occurs. While the difference in the mass contour of NaOH with various operating conditions can be seen in Figure 2.

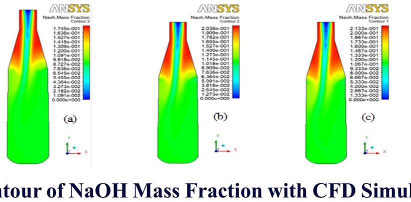

Figure 2. Contour of NaOH Mass Fraction with CFD Simulation: (a) C NaOH 18 g/L, T 145oC; (b) C NaOH 21 g/L, T 143oC; (c) C NaOH 22 g/L, T 141oC

The main focus of this research is to reduce the levels of lignin in wood chips by using the delignification process. Permitted lignin levels range between 18% - 22%, or it can be said that the digester works optimally if the remaining lignin content is constant at 20%. From the three contours above obtained different lignin levels, in variation (a), namely 18 g Na / NaOH concentration and 145 0C temperature, the remaining lignin level was 23.02 %, in variation (b), that is 21 g NaOH concentration / L and the temperature of 143 oC obtained lignin content of 19.97 %, and variation (c), namely 22 g / L NaOH concentration and 141 oC temperature obtained the remaining lignin content of 18.26%.

The product obtained from the study is that the contours of the Na-Lignate mass fraction contour with a variety of different operating conditions. The Na-Lignate component here acts as a product, and it is seen in the whole contour that the mass fraction of Na-Lignate increases throughout the digester as a result of its formation into the product. Seen in Figure 3.

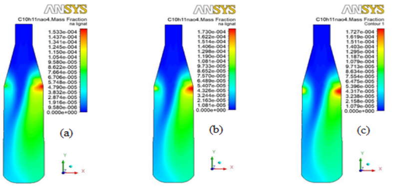

Figure 3. Contour of NaOH Mass Fraction with CFD Simulation: (a) C NaOH 18 g/L, T 145oC; (b) C NaOH 21 g/L, T 143oC; (c) C NaOH 22 g/L, T 141oC

The red color of the contour indicates the highest mass fraction while blue indicates the lowest fraction. It can be seen from the three contours above, when the inlet condition in blue indicates that no Na-Lignate component has been formed yet. Then on the right side the red color shows the highest mass fraction, indicating the most reactive zone where the most Na-Lignate is formed from the delignification reaction. The more Na-Lignate formed, the more Lignin component is converted so that the remaining Lignin level will be lower.

CONCLUSION

The comparison between experimental results and CFD simulation results using the ANSYS 19.2 program is not much different where the contours produced from the ANSYS 19.2 program have a significant gradient in the delignification digester inlet section. Simulation results show that the delignification process produces 19.97% lignin levels under 143 0C operating conditions and a concentration of 21 g / L NaOH.

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