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Control of an acid sulphite batch pulp digester based on a fundamental process model

André Kilian

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by

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Control of an acid sulphite batch pulp digester based on a fundamental process model

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Synopsis

The lack of measurements on a batch pulp digester necessitates the use of a model to control the product quality. In the production of dissolving pulps, the degree of polymerisation of the cellulose is the most important control variable. The aim of this study was to develop a model that can be used in a control strategy for the pulp digester. The model should therefore be capable of predicting the final degree of polymerisation of a cook based on the initial conditions.

A modelling strategy was used which combined the techniques of fundamental modelling and empirical modelling. The basic structure of the model was chosen from first principles. Simulation results from the model were compared with both experimental and the actual measured values for a set of cooks and the parameters in the model were adjusted to fit the data.

Excellent results were obtained by using this modelling technique. The accuracy of the model was measured by using the coefficient of variance. The coefficient of variance is calculated as the ratio of the variance between the model predicted values for the final degree of polymerisation and the actual measured values for a set of cook, and the mean of the predicted values. The model was verified against 35 actual cooks and a coefficient of variance of 10,7 was obtained, which can be interpreted as an average of 10% variance between the predicted and measured values. The normal coefficient of variance obtained at SAPPI SAICCOR by using the current model is between 20 and 30, and the results from this study indicate that a significant improvement would be possible if a fundamental model could be used in controlling the product quality.

The correlation coefficient obtained between these two sets of data was 0,77. This high value for the correlation coefficient indicates that the model is able to predict

changes in the final degree of polymerisation. This signifies that the model would be suitable for implementation in a control strategy, since any variations in the process would be predicted and corrected for.

Keywords: acid sulphite pulping, batch modelling, batch control, fundamental model, degree of polymerisation, wood degradation kinetics, empirical modelling, wood constituents.

Beheer van ‘n enkellading suur sulfiet pulpverteerder gebaseer op ‘n fundamentele model

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Sinopsis

Die gebrek aan meting op ‘n enkellading pulpverteerder noodsaak die gebruik van ‘n model in die beheer van produkkwaliteit. Tydens die produksie van oplosbare pulp is die graad van polimerisasie van die sellulose die belangrikste beheerde veranderlike. Die doelwit van hierdie studie was om ‘n model te ontwikkel wat gebruik kan word in ‘n beheerstrategie vir die pulpverteerder. Die model moet daarom die vermoë hê om die finale graad van polimerisasie te voorspel vir ‘n kook, gebaseer op die aanvanklike toestande.

‘n Modelleringstrategie is gebruik wat die tegnieke van fundamentele en empiriese modellering kombineer. Die basiese modelstruktuur is gekies uit eerste beginsels. Resultate van simulasies met die model is vergelyk met beide eksperimentele data en werklike aanlegdata en die parameters in die model is verander om aan die data te pas.

Uitstekende resultate is verkry deur van hierdie modelleringstegniek gebruik te maak. Die akkuraatheid van die model is gemeet aan die koëffisiënt van variansie. Die koëffisiënt van variansie word bereken as die verhouding van die variansie tussen die model-voorspelde waardes vir die finale graad van polimerisasie en die werklike gemete waardes vir ‘n stel kook data, en die gemiddeld van die stel voorspelde waardes. Die model is geverifiëer teen 35 werklike koke en ‘n koëffisiënt van variansie van 10,7 is verky, wat geïnterpreteer kan word as ‘n gemiddelde afwyking van 10% tussen die voorspelde en werklike waardes. Die normale koëffisiënt van variansie wat deur SAPPI SAICCOR verkry word is tussen 20 en 30 en die resultate van hierdie studie dui aan dat ‘n merkbare verbetering moontlik is indien ’n fundamentele model gebruik word vir die beheer van die produkkwaliteit.

Die korrelasie koëffisiënt wat verkry is tussen hierdie twee stelle data is 0,77. Hierdie hoë waarde vir die korrelasie koëffisiënt dui aan dat die model die vermoë het om veranderinge in die finale graad van polimerisasie te voorspel. Dit dui daarop dat die model geskik sal wees vir implementering in ‘n beheerstrategie, aangesien verandering in die produkkwaliteit voorspel kan word en vroegtydig gekorrigeer kan word.

Sleutelwoorde: suur sulfied verpulping, enkellading modellering, enkellading beheer, fundamentele model, graad van polimerisasie, hout afbraak kinetika, empiriese model, houtkomponente.

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Nomenclature

Symbol	Description	Units of measurement
a	Lignin reaction order in rate equations	
A	Strong acids concentration	mol/l
	Equilibrium to be considered in equation (8-5)	
b	Bisulfite reaction order in strong acid formation	
B	Normalisation factor in Arrhenius equation	
	Constant term in equation (8-5)	
c	Hydrogen reaction order in strong acid formation	
C	Numerator in equation (8-5)	
d	Reaction order of hemicellulose in hemicellulose degradation	
E	Activation energy	K
	Electrode potential	mV
k	Equilibrium constant for a reaction	
	Arrhenius temperature dependency f(T)	
k^o	Frequency factor in Arrhenius equation	
K_M	Constant in equation (2-4)	
[L]	Residual lignin concentration	%
M	Molecular weight	g/mol
	Concentration of metal ions in sulphite process	mol/l
n	Number of moles	mol
P	Pressure	bar
r	Reaction rate	mol/time
R	Recirculation rate	m^3/hr
t	Time	time
T	Temperature	K
V	Volume	m^3
X	Model predicted value	
Y	Actual or Measured value (see X)	

Greek

α	Reaction order of bisulphite in lignin reactions
β	Reaction order of hydrogen in lignin reactions
δ	Reaction order of hydrogen in cellulose reactions

γ	Hydrogen reaction order in hemicellulose degragation	
μ	Viscosity	cP
ν	Liquor-to-wood ratio	
ρ	Density	kg/m^3

Subscripts

a	Constant in Equation (2-4)
C	Concerning cellulose
HC	Concerning hemicellulose
i	Index
L	Concerning lignin
SA	Concerning strong acid
w	Weight
0	Initial