STUDY ON EFFECT OF SCALE FORMATION IN EVAPORATORS OF SUGAR INDUSTRY USING EXPERIMENTAL AND MATHEMATICAL MODELING

A. B. G. C. J. De Silva

(07/8212)

Thesis submitted in partial fulfillment of the requirements for the
Degree of Master of Science in Sustainable Process Development

Department of Chemical & Process Engineering

University of Moratuwa
Sri Lanka

November 2011

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ABSTRACT

This study focuses sugar factory evaporators in Sri Lanka. Multiple effect evaporators are employed in concentrating the clarified cane juice in sugar factories in Sri Lanka. Scale formation on heat transfer surfaces in sugar factory evaporators has a highly deleterious effect on specific energy consumption and production capacity. This thesis introduces combined experimental and mathematical modeling approach to study the effect of rate of scale formation in evaporators. Prior to develop mathematical model the rate of scale formation was experimentally investigated by analyzing evaporator scale, clear juice and syrup in two sugar factories in Sri Lanka. The model was developed using MATLAB software. The built mathematical model consists of two fouling phenomenal namely, particulate fouling and chemical precipitation fouling. The model shows the development of scale in each evaporator and temperature variation in each evaporator. The model also indicates the effect of following a scale reduction technique by comparing temperature variation in each evaporator before and after using a scale reduction technique.

DEDICATION

Dedicated with gratitude

To my loving **PARENTS**

For being

The greatest pliers of my life.

ACKNOWLEDGEMENT

Completion of the MSc thesis was one of the biggest challenges I ever had in my life. Without the support, guidance and patience of the following people this would not have been success.

In the first place my heartfelt gratitude goes to my supervisor, Dr. P.G.Rathnasiri, Senior Lecturer in the department of Chemical and Process Engineering for the endeavor guidance giving towards me throughout my master's degree program in Sustainable Process Development. Thank you very much for screening me the right way to complete my research as well. I gratefully acknowledge Prof. Ajith De Alwis to turn my way to do a Master's degree by initiating the courage. I would like to thank Prof. Bernt Lie, Telemark University, Norway for giving me guidance to carry out my research in the initial stage of evaporator modeling.

My special thanks go to Dr.H.K.Sunil, former director, Sugarcane Research Institute for the helping hands given towards me to select a research title and Dr.N.C. Kumarasinghe, Director, Sugarcane Research Institute for giving me the necessary assistance to conduct my research in the institute premises.

Without the help of the Factory Manager, Pelwatte Sugar Industries Limited, Mr. Palitha Prematunga and Factory Manager, Sewanagala Sugar Industries limited, Mr. Kamal Silva, Laboratory Officer, Mr.H.Premarathne this research would not be success. Thank you very much for helping me to gain knowledge on sugar production process and providing necessary arrangements to obtain samples whenever it is necessarry. I would like to thank all the staff members of the laboratories of Pelwatte Sugar Industries Limited and Sewanagala Sugar Industries Limited. My special thanks go to all the members in the Chemistry Division of Sugarcane Research Institute for supporting me to do chemical analysis of the samples.

The support given by Mr.Anushka Perera,to build up the mathematical model in matlab is highly admired. It is a pleasure for me to thank Mr.Suroj Maharajan and Mr.Udara Sampath to start working with me for modeling sugar industry evaporators and putting me into the background to model sugar industry evaporators. Thank you Dr.Deshai Botheju for showing me the correct path to build up the mathematical model. I would like to thank Mr.Thilina for assisting me to do the modifications of the model.

My sincere gratitude goes to Director, Industrial Technology Institute, A.M. Mubarak, and Deputy Director Research and Development Dr.Shanthi Wilson Dr.Jaanaki Goonerathne, Head, Food Technology Section, for allocating time for me to complete my research thesis. Thank you Dr. Jaanaki, for releasing me to write my thesis during the working hours of Industrial Technology Institute.

My special thanks go to Ms.Sudeepama Walliwala and Mrs.Erandi Wijedeera for assisting me to complete the thesis in working time while managing the work in the section.

None of these would not have been possible without the patience of my family. I greatly appreciated the help given towards to my parents, my life partner and my son.

It is a pleasure for me to thank the director, Post Graduate Division,Mrs.Kumuduni and the staff members of the postgraduate institute, for providing me the necessary arrangements to extend the time for working with the MSc.

I believe that my research would make a small contribution to the vast ocean of scientific research conducted in the field of Sugar Technology.

A.B.G.C.J. De Silva

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NOMENCLATURE

F	Inlet juice flow rate(Tonnes/hr)
L_i	Out let juice flow rate (i=1 to 4)(Tonnes/hr)
V_i	Steam/vapor flow rate(i=0 to 4)(Tonnes/hr)
x_i	Brix% in juice (i=0 to 4)
m_i	Mass inside the vessel.(Tonnes)
T_i	Boiling point temperature of juice. (i=0 to 4) (^{o}C)
T_f	Temperature of juice at feed. (^{o}C)
T_s	Temperature of steam. (^{o}C)
U_i	Internal energy. (kJ)
H	Enthalpy. (kJ)
C_p	Heat capacity of juice. (kJ/kg K)
$\widehat{H}_f$	Enthalpy of feed flow per unit mass.(kJ/kg)
$\widehat{H}_L$	Enthalpy of out flow per unit mass.(kJ/kg)
V_i	Vapor flow rate from evaporator.(i=0 to 4)(kg/hr)
λ_i	Latent heat of steam/vapor.(i=0 to 4) (kJ/kg)
Q_i	Heat produce in evaporator.(kJ)
W_{ai}	Mechanical work done. (i=1 to 4)(kJ)
ρ_i	Density of juice inside evaporator 1.(kg/m3)
U_i	Overall heat transfer coefficient
r_i	Radius of calandria tubes (i=1 to 4)
t_i	Thickness of scale on calandria tube (i=1 to 4)
n_i	Number of tubes in evaporator (i=1 to 4)
h_{steam}	Convective heat transfer coefficient in steam side

h_{juice}	Convective heat transfer coefficient in juice side
R_{wall}	Resistance to heat transfer from the wall
R_{scale}	Resistance to heat transfer in scale
k_{wall}	Thermal conductivity of calandria tube wall (kW/K)
k_{scale}	Thermal conductivity of evaporator scale (kW/K)
A_i	Heat flow area in calandria(i=1 to 4) (m^2)
A_i'	Cross section area of tube inside calandria (m^2)
T	Temperature (^{0}C)
p	Purity (%)
μ	Magnetic field strength
E	Induces Electric field vector
B	Magnetic field strength vector
ω	Angular velocity of the current wave ($rads^{-1}$)
s	Line vector along the circumferential direction
r	Distance from the circumferential direction (m)
a	Acceleration to the particle
k_d	Deposition rate coefficient(hr^{-1})
k_{con}	Consolidation Rate coefficient (hr^{-1})
C	Concentration of particles in solution (kg/m^3)
k_{rem}	Removal Rate coefficient (hr^{-1})
C_b	Concentration of the substrate in the bulk fluid (kg/m^3)
C_e	Equilibrium concentration of the substance at the conditions of the interface
k_d	Kinetic rate constant (hr^{-1})
n	Order of reaction

γ	Evaporation rate (kg/hr.m^2)