International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 09 | Sep 2019 www.irjet.net p-ISSN: 2395-0072

SIMULATION OF SAND BATH HEATER

Ganesh Ugale[1], Pranav Bairagi[2], Mangesh Mehtre[3]

[1]Chemical Engineer, Pune Maharashtra, India
[2]Mechanical Engineer, Pune Maharashtra, India
[3]Mechanical Engineer, Pune Maharashtra, India

Abstract - *Laboratory experiments in chemical engineering can be modeled by defining heat and material balance and considering transport phenomena in non-stationary conditions. Usually, these Equations have no analytical solution and students cannot solve the problem easily to compare experimental results with theory. In this the use of MATLAB is presented as a powerful tool in order to solve chemical engineering problems numerically. The experiment consists of three gas-solid fluidized baths, one of them prepared with two heaters and temperature transmitters to obtain non stationary data. A fluidized bath is considered a globalize system owing to perfect mixing, so temperature gradients are negligible. The other two baths have different diameters and work at ambient temperature to give steady-state results for hydrodynamic conditions. The combination of theory, experimental results and simulation improves learning and safety in operation.*

Key Words: sand bath, fluidized bed, heat transfer, mathematical modelling, simulator

1. INTRODUCTION

1.1 Sand bath heater

A sand bath is a common piece of laboratory equipment made from a container filled with heated sand. It is used to provide even heating for another container, most often during a chemical reaction.A sand bath is most commonly used in conjunction with a hot plate or heating mantle. A beaker is filled with sand or metal pellets (called shot) and is placed on the plate or mantle. The reaction vessel is then partially covered by sand or pellets. The sand or shot then conducts the heat from the plate to all sides of the reaction vessel. This technique allows a reaction vessel to be heated throughout with minimal stirring, as opposed to heating the bottom of the vessel and waiting for convection to heat the remainder, cutting down on both the duration of the reaction and the possibility of side reactions that may occur at higher temperatures. [1].

A variation on this theme is the water bath in which the sand is replaced with water. It can be used to keep a reaction vessel at the temperature of boiling water until all water is evaporated (see Standard enthalpy change of vaporization.)Sand baths are one of the oldest known pieces of laboratory equipment, having been used by the alchemists The fluidized bath is a container filled with dry inert particles of Aluminum oxide. When a gas flow is passed through the particles via a Porous distribution plate, the particles are separated and suspended in the gas flow and take on the appearance of a boiling liquid. Apart from circulating and flowing like a liquid, fluidized particles exhibit excellent heat transfer characteristics. When fluidized particles are heated, heat is distributed quickly and evenly throughout the bath and Transferred rapidly to objects submerged in the bath. The bath temperature can be adjusted easily to the point at which you wish to calibrate or run a test.

Fluidized solids have no melting or boiling point. Therefore, solidification which takes place in cooling salt baths and fumes from hot oil bath is eliminated. Fluidized solids are dry and relatively inert, making the medium safe and clean compared conventional to liquid systems. [2]

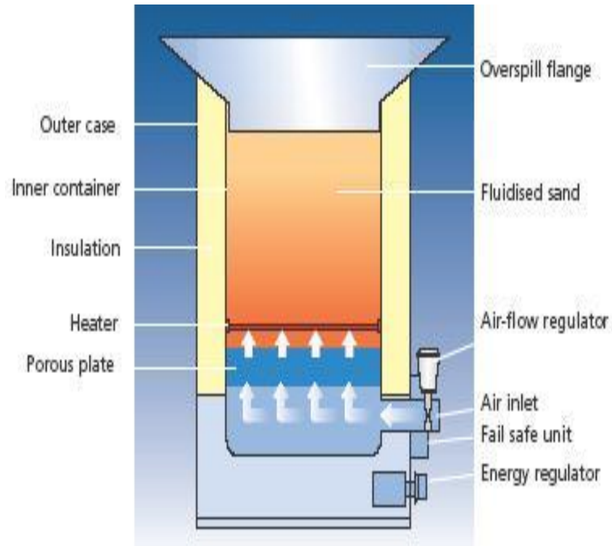


FIGURE1 Schematic of sand bath heater

1.1.1 Advantage of sand bath:

i. Rapid heating and cooling
ii. Bath media do not splash
iii. Vessels are not wetted or coated by bath
iv. Bath media remain clean and do not decompose

1.1.2 Features:

Accurate uniform temperature control over a wide range
Safe operation- clean, dry, inert, nontoxic
Rapid heating- high heat transfer rate

Safe for delicate instruments
Medium cannot evaporate or solidify

1.1.3 Application of sand bath:

The sand bath is designed for applications requiring a constant high temperature source for calibration. It is used to provide even heating for another container, most often during a chemical reaction.

2. EXPERIMENTAL SETUP

A process flow diagram of the pilot plant is presented in Fig. A picture of the system is shown in below Fig. The pilot plant consists of three sand baths, two of them made of methacrylate (200mm and 250mm diameter) to operate at room temperature and another one made of stainless steel (250mm diameter) to study high temperatures (up to 200C). The baths are half-filled with alumina particles of 170±210 m. When air is flowed at the bottom of the sand baths the bed experiences a volumetric expansion. Above a certain flow rate all the particles are suspended chaotically (perfectly mixed): this is called fluidization. Under these conditions the solid has the same appearance as a boiling liquid, with breaking bubbles, as it is illustrated in Fig.3.Air is taken from outside and after filtration is pumped into the three baths with a low-pressure blower. Flow rates for each bath are controlled with a valve on each branch (one per bath). Flow rates are measured using air rotameters in the range 1.8±18±m3/h. Pressure drop is also measured using water manometers.

The metal bath has two cartridge heaters (1600W each) controlled by manual potentiometers connected to an automatic controller (LS-3200, Design Instruments). The temperature is measured with two thermocouples inserted in the bath at a certain height. [3]

3. SIMULATION:

Simulink is a software package used for modeling, analyzing, and simulating a wide variety of dynamic systems. Simulink provides a graphical interface for constructing the models. It has a library of standard components, which makes block diagram representation easier and quicker. Simulink is a ready-access learning tool for simulating operational problems found in the real world because simulation algorithms and parameters can be changed in the middle of simulation with intuitive results. It is particularly useful for studying the effect of nonlinearities on the behavior of the system. [4]

3.1. Features of Simulink

i. A comprehensive library for creating linear, nonlinear, discrete, or multi-input/ output systems.
ii. Mask facility for creating custom blocks.
iii. Unlimited hierarchical model structure.
iv. Scalar and vector connections.
v. Interactive simulations with live display.
vi. One can easily perform what-if analyses by changing model parameters.
vii. Simulink block library can be extended with special purpose block sets.

4. SIMULATION PROVIDES:

I. Efficiency Cost quantification in terms of savings or avoidance.

i. Higher mission availability.
ii. Increased operational system availability.
iii. Transportation avoidance.
iv. Reduced/eliminated expendable costs.
v. Less procurement and operational costs.

II. Effectiveness Positive contribution that are seldom quantified as

i. Improved proficiency/performance
ii. Provides activities otherwise impossible short of combat
iii. Provides neutral and opposition forces
iv. Greater observation/assessment/analysis capability.

III. Risk reduction

i. Safety
ii. Environment
iii. Equipment

4.1. Application of simulation:

Application areas for simulation are numerous and diverse. A list of some particular kinds of problems for which simulation has been found to be a useful and powerful tool is as follows:

i. Designing and analyzing of systems
ii. Evaluating hardware and software requirements for a computer system
iii. Evaluating a new military weapons system or tactic
iv. Determining ordering policies for an inventory system
v. Designing communications systems and message protocols for them
vi. Designing and operating transportation facilities such as freeways, airports, subways, or ports
vii. Evaluating designs for service organizations such as hospitals, post offices, or fast food restaurants
viii. Analyzing financial or economic systems. [4]

5. MATHEMATICAL MODEL FOR FLUDISATION AND HEAT TRANSFER

In order to test the system, ten experiments were carried out in the metal sand bath. Fluidization and heat transfer variables were studied for 10 to 100 kg of alumina at three different heating powers. Results are shown in result section.

To model the system a globalized state is considered for the sand due to fluidization conditions. Equation 1 is an ODE (ordinary differential equation) which describes the heat balance for the fluidised sand bath, where the change in temperature of alumina is proportional to power, enthalpy of the air and heat loss. Equation 2 is an experimental fit which describes the change in temperature of the air depending on sand temperature. Ideally in a perfectly mixed tank both temperatures should be

Equal to

$$msCp(\frac{dTs}{dt}) = W - mCpair\ (Tair\ out - Tair\ in) - q_p \ldots\ldots\ldots\ldots(1)$$

$$Tair\ out = 0.962Ts - 2.822 \ldots\ldots\ldots\ldots(2)$$

An analytical solution for the model equations can be found under some assumptions. However, Equation 2 introduces non-ideal behavior. Furthermore, mass flow rate of inlet air is controlled during the experiment because the increasing temperature decreases the density and increases volumetric flow rate of air inside the bath. This can be implemented in the model by simply considering the ideal gas law

5.1. Simulink model

Simulink provides an additional educational approach to describe and solve the dynamics system. For these reason we consider MATLAB useful tool for educational purpose. More complex problems, such as transport phenomenon equations, could require computer fluid at dynamic modeling (CFD). This is also possible with MATLAB in conjunction with FEMLAB. Therefore it is good choice for the future. Modular programming gives the possibility of dividing the problem into piece for better understanding. Our system has been divided in two main blocks. The first block is the heat balance; the second block is an additional control box for the power. Following fig shows the graphical user interface; manual or automatic control can be selected by manual switching.

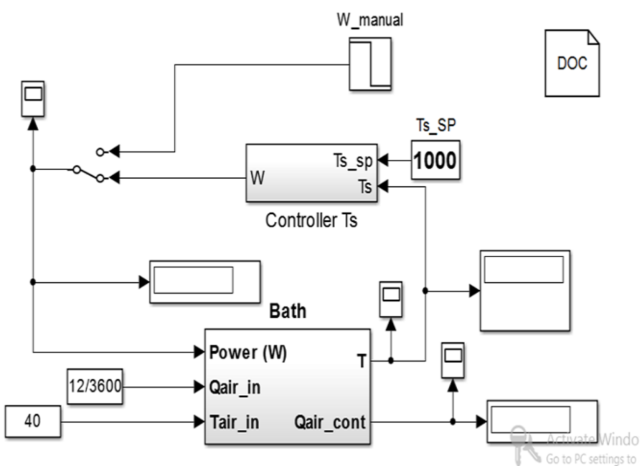


FIGURE 2 Simulink model

5.2. Main parameter use in model:

By changing the main parameter we get different result. By changing mass parameter we get different value of W with keeping time constant.

```
clear all
close all;
clc;
%%
InitialTime=0;
FinalTime=284;
SOLID=[];
Tso=44;
Ms=12;
Cps=1.0040e3;
Density_S=3960;
Dp=2.0000e-4;
INSULATION=[];
Kins=0.0340;
xins=0.1;
Troom=25;
Text=40;
hconv_ext=20;
AIR=[];
Cpa=1.0229e3;
Qair_in=12;
Tair_in=40;
%%
```

FIGURE 3 Algorithm file

All the heat contribution are separated in function. Following Fig shows the heat balance for bath model.

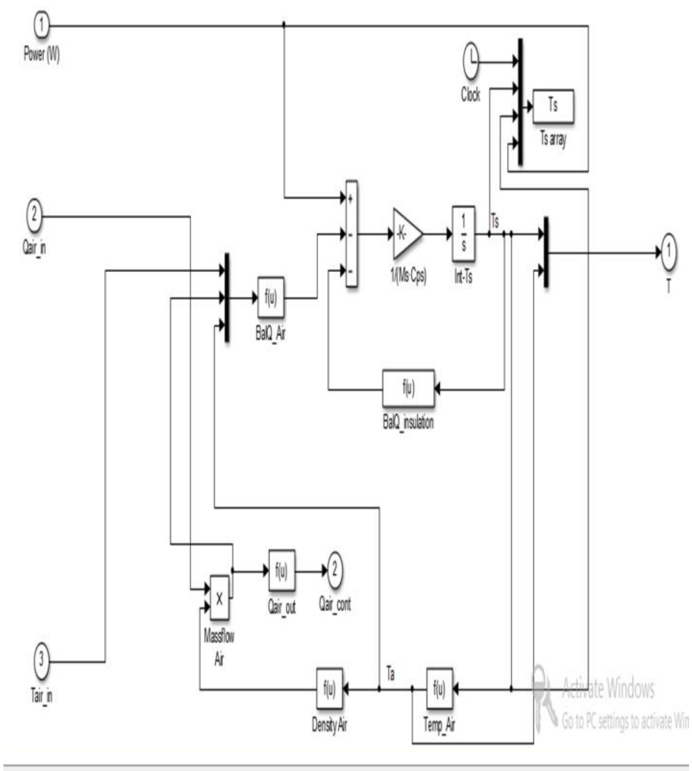


FIGURE 4 Simulink model subsystems

The inside of controller is revealing in following figure. Power is manipulated variables while solid temperature is the set point.

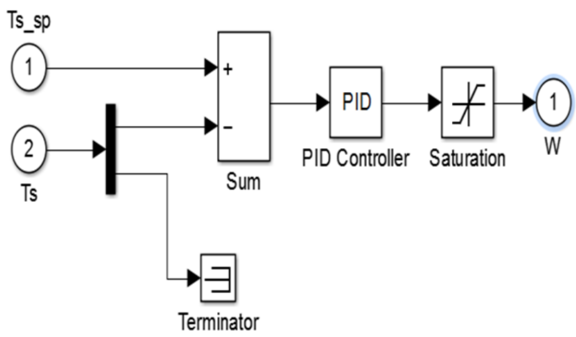


FIGURE 5 PID controller

The simplest model for our system is well described by Equation 1 where all the values apart from solid temperature and outlet air temperature (equal to solid temperature in ideal conditions) and time are constant. In this case, direct analytical solutions can be successfully attempted. However, most of the models cannot be solved analytically.

As recommended in MATLAB help, `ode45' is the best function to apply as a `first try' for most problems. This method is based on an explicit Runge-Kutta 4,5-formula, the Dormand-Prince-Pair. The MATLAB commands are as follows where all variables can be easily identified comparing to Equation 1

5.3. Various Simulink blocks use in model and their descriptions:

TABLE NO 1

1	Scope	Display signals generated during simulation
2	Constant	Generate constant value
3	Display	Show value of input
4	Step function	Generate step function
5	Subsystem	Represent system within another system
6	Input	Create input port for subsystem
7	Clock	Display and provide simulation time
8	To workspace	Write data to workspace
9	Output	Create output port for subsystem
10	Mux	Combine several input signal into vector
11	Gain	Multiply input by constant
12	Integrator	Integrate signal
13	Function	Apply specified expression to input
14	Sum	Add or subtract
15	Product	Multiply and divide scalars and non-scalars or multiply an invert matrix
16	Saturation	Limit range of signal
17	PID controller	Simulate continuous or discrete time PID controller
18	Terminator	Terminate unconnected output port

TABLE NO 2

No.	Mass(kg)	Time(min)	W(watt)	Solid temp $(Ts)^0C$
01	10	50	720	323.5
02	20	50	749.5	326
03	30	50	1022	322.5
04	40	50	1759	311.5
05	50	50	2941.1	290
06	60	50	4439.01	268
07	70	50	5100	235
08	80	50	5100	211.7
09	90	50	5100	193
10	100	50	5100	178.8

5.4. Various equations use in our model

5.4.1. Air density

(1+150/1000)*28.92/(0.08206*(273.15+Ts))

5.4.2. Qair out

Ts/((1+150/1000)*28.92/(0.08206*(273.15+Text))

5.4.3. Insulation of sand bath

(1/(Xins / Kins+ 1 / hconvext))*3.1416*(0.25+2Xins)*0.4*(Ts –Troom)

All the value for the physical properties was extracted from the most common chemical engineer handbook from the library.

6. OBSERVATION TABLE

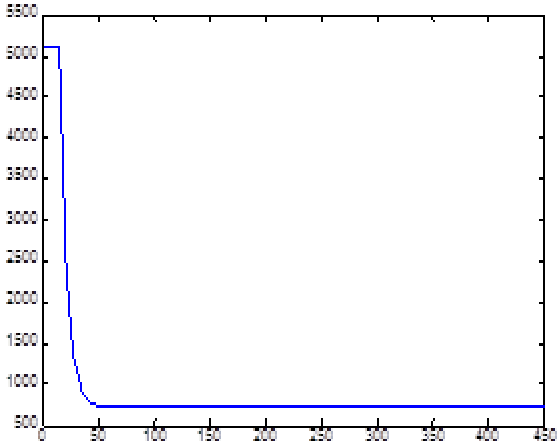
TABLE NO 2

No.	Mass(kg)	Time(min)	W(watt)	Solid temp $(Ts)^0C$
01	10	50	720	323.5
02	20	50	749.5	326
03	30	50	1022	322.5
04	40	50	1759	311.5
05	50	50	2941.1	290
06	60	50	4439.01	268
07	70	50	5100	235
08	80	50	5100	211.7
09	90	50	5100	193
10	100	50	5100	178.8

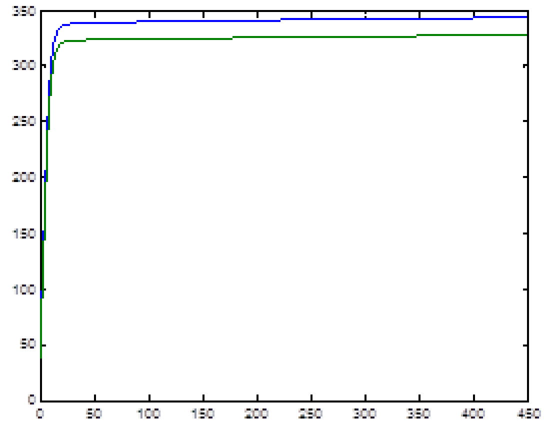
For study of dynamic behavior of the sand bath we have check how various parameters affect the system. For study purpose we vary the solid mass values in our main parameter file and simulation time is 50cycles with set point value1000. Take down the following readings and graphs are shown in result section.

7. RESULTS

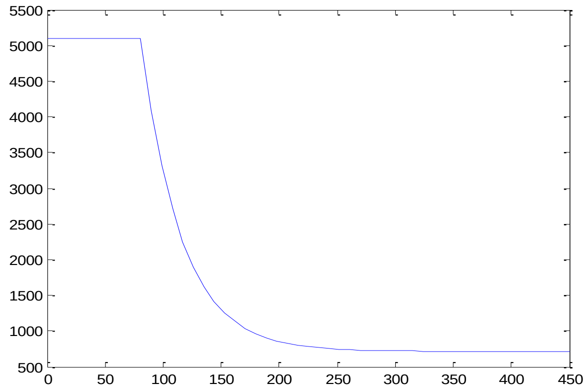
From above observation table we have plotted various graphs of time versus temperature and time versus power, graph



Graph1: For 10kg Temperature Vs Time

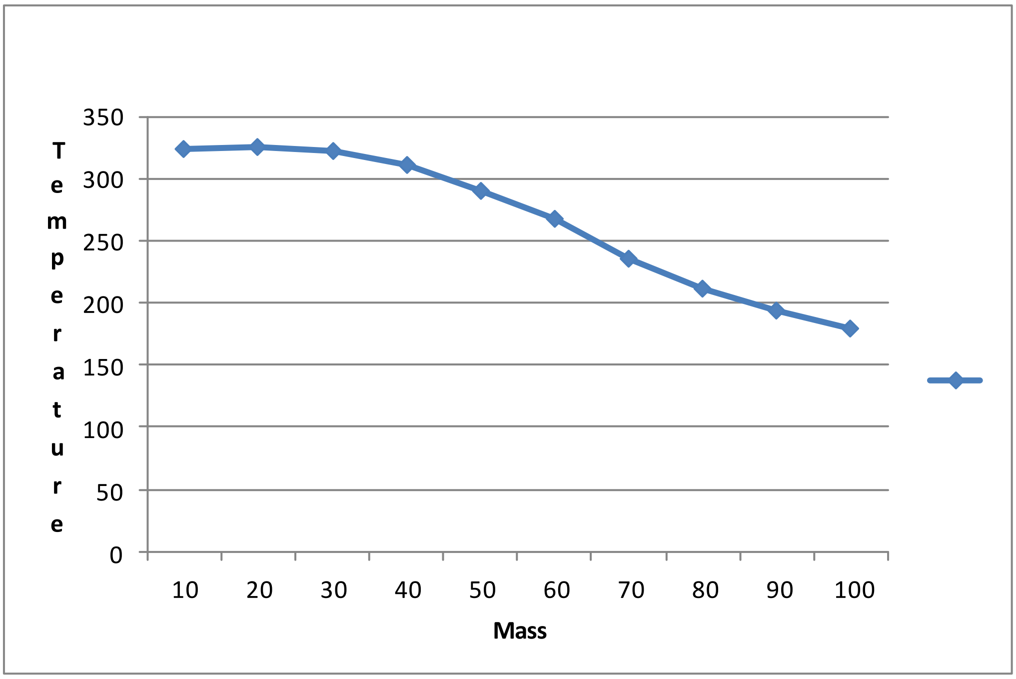


Graph 2: 30 kg t vs W



Graph 3: For 100 kg t vs w

8. SUMMARY



Graph 4 : Mass Vs Temperature

This graph shows that the relationship between mass and temperature. If mass increases temperature will decreases. Following equation shows the relations between Temperature and mass; they show that mass and temperature is inversely proportional to each other. Therefore mass will increases temperature get decreases

Energy = Mass*specific heat capacity*temperature

9. CONCLUSION

With the help of modeling and simulation, using equations we can carry out the simulation which help to study the dynamics of any system. Overall study of modeling and simulation helps to understand the environmental aspects and safety, save money and time, visualization, allow you to observe system behavior over time at any level of detail. A simulation model can capture much more details than an analytical model which provide for increase accuracy and more precise forecast

REFERENCES

[1] Kevin D. Seibert and Mark A. Burns, Simulation of Fluidized Beds and Other Fluid-Particle Systems Using Statistical Mechanics Dept. of Chemical Engineering, University of Michigan, Ann Arbor, MI 48109

[2] J. R. Dormand and P. J. Prince, A family of embedded Runge-Kutta formulae, J. Comp. Appl.Math., 6, 1980, pp. 19±26

[3] Mosier, N.; Wyman, C.; Dale, B.; Elander, R.; Lee, Y. Y.; Holtzapple, M.; Ladisch, M. Features of Promising Technologies for Pretreatment of Lignocellulosic Biomass. Bioresour. Technol. 2005, 96, 673.

[4] Allen, S. G.; Schulman, D.; Lichwa, J.; Antal, M. J., Jr.; Jennings, E.; Elander, R. A Comparison of Aqueous and Dilute Acid Single Temperature Pretreatment of Yellow Poplar Sawdust. Ind. Eng. Chem. Res. 2001, 40, 2352

[5] Mosier, N.; Wyman, C.; Dale, B.; Elander, R.; Lee, Y. Y.; Holtzapple, M.; Ladisch, M. Features of Promising Technologies for Pretreatment of Lignocellulosic Biomass. Bioresour. Technol. 2005, 96, 673

[6] Allen, S. G.; Schulman, D.; Lichwa, J.; Antal, M. J., Jr.; Jennings, E.; Elander, R. A Comparison of Aqueous and Dilute Acid Single Temperature Pretreatment of Yellow Poplar Sawdust. Ind. Eng. Chem. Res. 2001, 40, 2352.

[7] Heitz, M.; Capek-Menard, E.; Koerberle, P. G.; Gagne, J.; Chornet, E.; Overend, R. P.; Taylor, J. D.; Yu, E. Fractionation of Populus tremuloides at the Pilot Plant Scale: Optimization of Steam Pretreatment Conditions Using the STAKE II Technology. Bioresour. Technol. 1991, 35, 23.

[8] Negro, M. J.; Manzanares, S. P.; Ballesteros, I.; Oliva, J. M.; Cabanas, A.; Ballesteros, M. Hydrothermal Pretreatment Conditions to Enhance Ethanol Production from Poplar Biomass. Appl. Biochem. Biotechnol. 2003, 105, 87

[9] Tucker, M. P.; Farmer, J. D.; Keller, F. A.; School, D. J.; Nguyen, Q. A. Comparison of Yellow Poplar Pretreatment Between NREL Digester and Sunds Hydrolyzer. Appl. Biochem. Biotechnol. 1998, 70– 72, 25.

[10] Bobleter, O. Hydrothermal Degradation of Polymers Derived from Plants. Prog. Polym. Sci. 1994, 19, 797.

[11] Kim, Y.; Mosier, N. S.; Ladisch, M. R. Enzymatic Digestion of Liquid Hot Water Pretreated Hybrid Poplar. Biotechnol. Prog. 2009, 25, 340.

[12] Bonn, G.; Concin, R.; Bobleter, O. Hydrothermolysis- A New Process for the Utilization of Biomass. Sci. Technol. 1983, 17, 195.

[13] Lloyd, T.; Wyman, C. E. Combined Sugar Yields for Dilute Sulfuric Acid Pretreatment of Corn Stover Followed by Enzymatic Hydrolysis of the Remaining Solids. Bioresour. Technol. 2005, 96, 1967.

[14] Grous, W. R.; Converse, A. O.; Grethlein, H. E. Effect of Steam Explosion Pretreatment on Pore Size and Enzymatic Hydrolysis of Poplar. Enzyme Microb. Technol. 1986, 8, 274.

[15] Brownell, H. H.; Saddler, J. N. Steam Pretreatment of Lignocellulosic Material for Enhanced Enzymatic Hydrolysis. Bio-technol. Bioeng. 1987, 25, 228.

[16] Studer, M. H.; DeMartini, J. D.; Brethauer, S.; McKenzie, H. L.; Wyman, C. E. Engineering of a High-Throughput Screening System to Identify Cellulosic Biomass, Pretreatments, and Enzyme Formulations That Enhance Sugar Release. Biotechnol. Bioeng. 2010, 105, 231.

[17] Incropera, F. P.; DeWitt, D. P. Introduction to Heat Transfer; John Wiley and Sons: New York, 2002.

[18] Martin, H. Heat Transfer Between Gas Fluidized Beds of Solid Particles and the Surfaces of Immersed Heat Exchanger Elements, Part I. Chem. Eng. Proces. 1984, 18, 157.

[19] Martin, H. Heat Transfer Between Gas Fluidized Beds of Solid Particles and the Surfaces of Immersed Heat Exchanger Elements, Part II. Chem. Eng. Proces. 1984, 18, 199.

[20] Ackeskog, H. B. R.; Almstedt, A. E.; Zakkay, V. An Investigation of Fluidized Bed Scaling: Heat Transfer Measurements in a Pressurized Fluidized-Bed Combustor and a Cold Model Bed. Chem. Eng. Sci. 1993, 48, 1459.

[21] Molerus, O.; Burschka, A.; Dietz, S. Particle Migration at Solid Surfaces and Heat Transfer in Bubbling Fluidized Beds-II. Prediction of Heat Transfer in Bubbling Fluidized Beds. Chem. Eng. Sci. 1995, 50, 879.

[22] Pisters, K.; Prakash, A. Investigations of Axial and Radial Variations of Heat Transfer Coefficient in Bubbling Fluidized Bed with Fast Response Probe. Powder Technol. 2011, 207, 224.

[23] Zabrodsky, S. S. Hydrodynamics and Heat Transfer in Fluidized Beds; M.I.T. Press: Cambridge, 1966.

[24] MathWorks Inc. MATLAB 2011b [computer program]; Natick, MA, 2011.

[25] McKenzie, H. L. Tracking Hemicellulose and Lignin Deconstruction During Hydrothermal Pretreatment of Biomass. Ph.D. Thesis, University of California Riverside, Riverside, CA, June 2012.