Modeling of Limestone Calcination Using Joule Heating

Ramakrishna Machiraju, Professor & Head
Ravichand Kancharla*, Associate Professor
Corresponding Author e-mail: ravichand.kancharla@bvrit.ac.in

Department of Chemical Engineering,
Padmasri Dr. B.V.Raju Institute of Technology, Narsapur,
Medak Dist, AP INDIA– 522301

COMSOL Conference, Bangalore
Nov 4-5, 2011

Motivation

- Rapid heating of lime stone
  - the recent research interest evaluated by Fall (2011)
  - Savings in energy projected
- Microwave heating of Alumina
  - modeled using COMSOL by Suryanarayana (2011)
- This presentation demonstrates the COMSOL capability to model joule heating of limestone with reaction.

Model details

- Physics used
  - Joule heating
  - Transport of Diluted species
- Geometry
  - 15*15*1 mm limestone particle with entire surface exposed for heating
- Mesh
  - Physics controlled mesh with fine element size
- Time dependant study (0-20 min heating time)

Joule Heating

- Initial condition
  - T=303.15K and V=220 Volts.
- Influx range
  - 500000 (rapid heating) - 500 W/m^2 (slow heating).

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u}_{trans} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q + W_p$$

$$\nabla \cdot \mathbf{J} = Q_j$$

$$\mathbf{J} = \sigma \mathbf{E} + \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}_e$$

$$\mathbf{E} = -\nabla V$$

Transport of Diluted Species

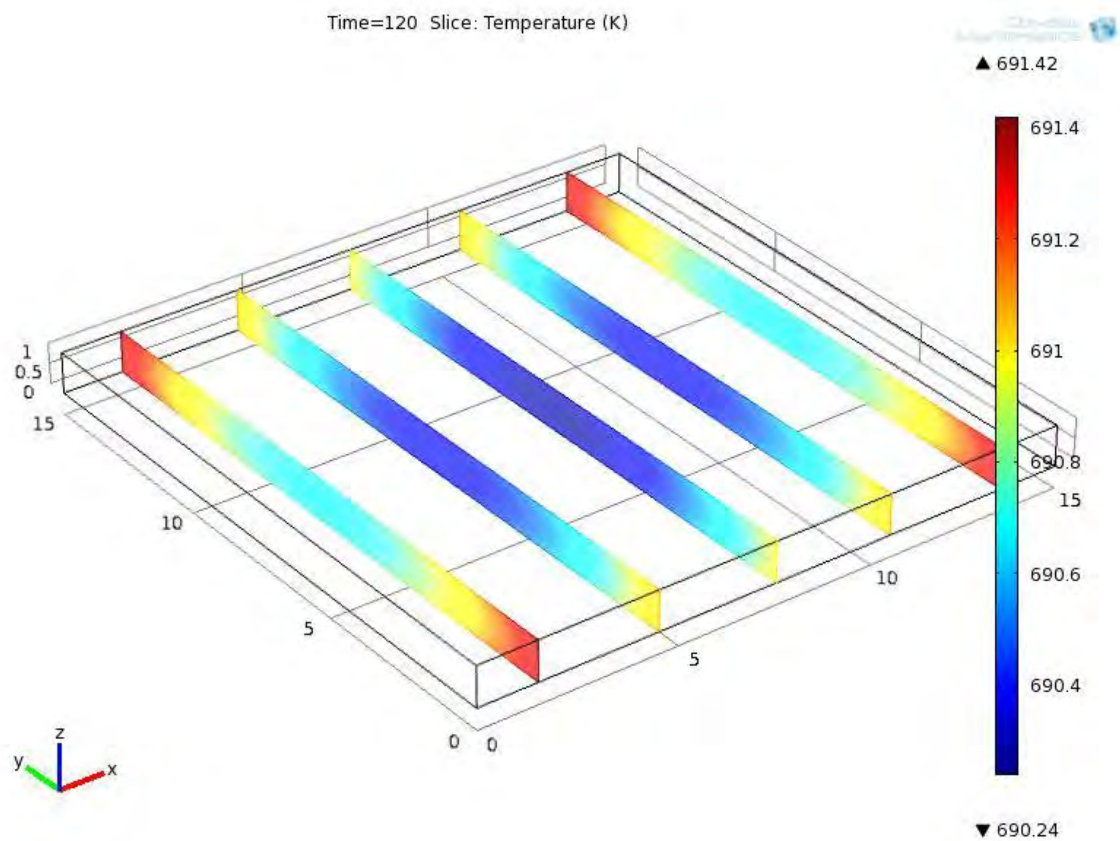
$$\frac{\partial c_i}{\partial t} + \nabla \cdot (-D_i \nabla c_i) = R_i$$

$CaCO3 ==> CaO + CO_2$

$$\mathbf{N}_i = -D_i \nabla c_i$$

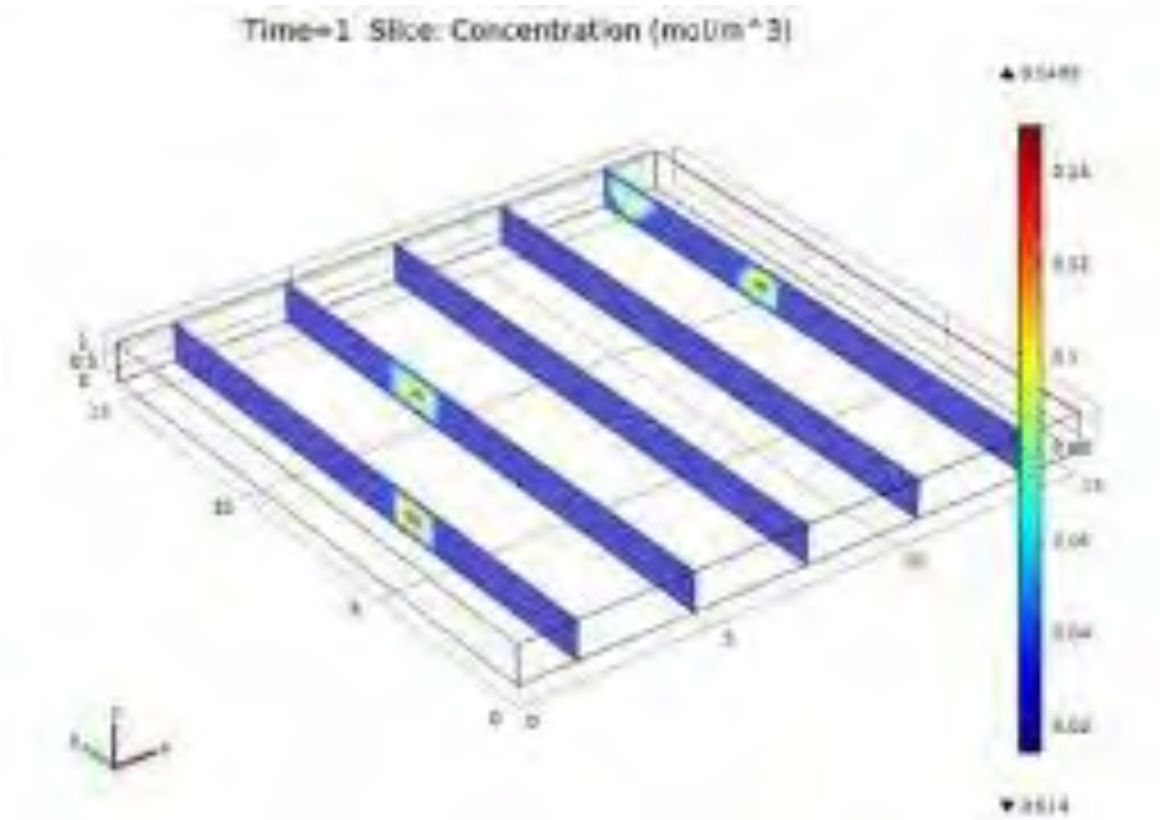
- Rate expression: Rj=k*Cj
- Reaction Rate Constant k= A*exp(−E/RT)
  - Frequency factor, $A=9.67*10^{24}\ hr^{-1}$
  - Activation Energy, E= 1092.947 KJ/mol
  - Convective Inward flux= 0.1 $mol/m^2.s$
  - Mass transfer coefficient= 0.0833 m/s
  - CO2 concentration in bulk phase = 0.002 mol/m^3
- Diffusion of CO_2
  - DCO2 = 1.39e-8 m^2/s

Results (Heating)



Inward Flux, W/m2	Time, seconds (to reach 700C)
$5*10^5$	1
$5*10^4$	12
$5*10^3$	120
$5*10^2$	1200

Results (CO_2 Concentration)



- Uniform concentration of 0.014 mol/m^3

Conclusion

- COMSOL capability demonstrated
- Useful to design the experiments

References

- Fall W, S. M. Allan, H. S. Shulman, "Rapid limestone calcination using Microwave Assist Technology", 35rd International Conference & Exposition on Advanced Ceramics and Composites ICACC-S8-023-2011
- Suryanaraya Murthy P, Srinath M S, Sharma A K, Pradeep Kumar, "An FEM approach to analysis of microwave heating of alumina in Multi-mode applicator", Int. Conference on Mathematical modeling and applications to industrial problems, NIT Calicut, March 28-31, 2011.
- Grégoire, Colette, Joesten, P.K., and Lane, J.W. Jr., 2007, Use of borehole-radar methods to monitor a steam-- enhanced remediation pilot study at a quarry at the former Loring Air Force Base, Maine: U.S. Geological Survey Scientific Investigations Report 2006–5191, 35 p.
- Boateng Akwasi A., Rotary Kilns-Transport Phenomena and Transport Processes, page-277, Butterworth-Heinemann Elsevier (2008)

ACKNOWLEDGMENT

- Authors would like to thank the management of Padmasri Dr. B. V. Raju Institute of Technology for providing the Simulation laboratory facilities