

Bhopal and Bagasse: Understanding Combustion Using Mathematics

Jane Sexton

Maritime Operations Division, DSTO

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 01 OCT 2003		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Bhopal and Bagasse: Understanding Combustion Using Mathematics				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Maritime Operations Division, DSTO				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM001929. Proceedings, Held in Sydney, Australia on July 8-10, 2003., The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline

- What is ignition?
- Describe two examples
 - Bhopal
 - Bagasse
- Mathematics of combustion
- Analytic tools
- Outcomes

What is ignition?

- Semenov
 - constant temperature
- Frank-Kamenetskii
 - temperature gradient
 - thermal runaway
 - chain reactions

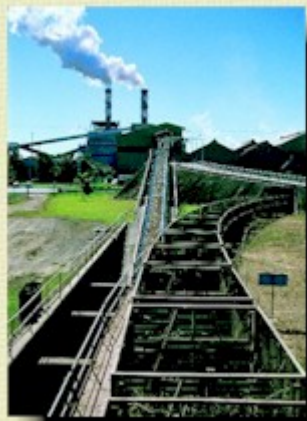
Bhopal Incident 1984

- Methyl isocyanate
- Water intrusion
- Pressure explosion



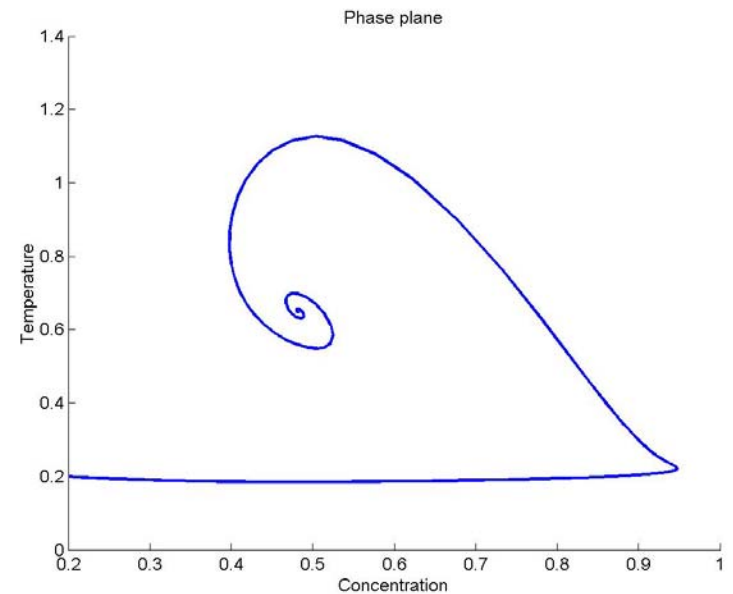
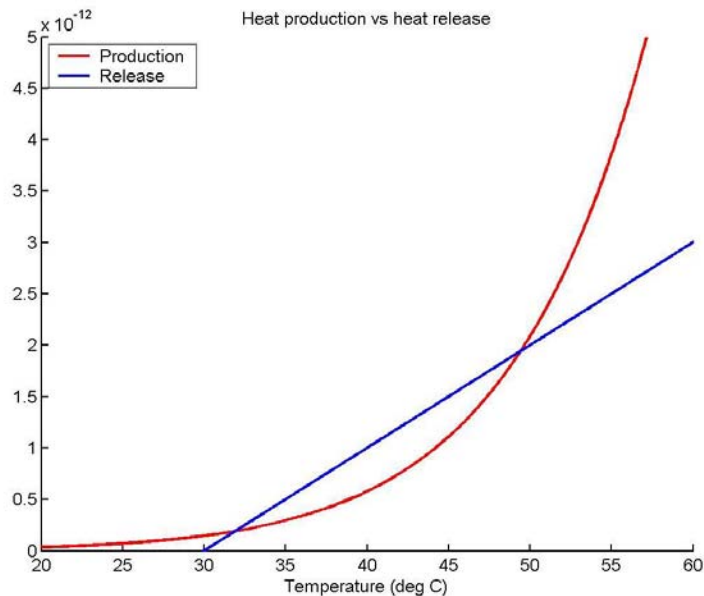
Bagasse

- Sugarcane residue
- Large piles
- Moisture content



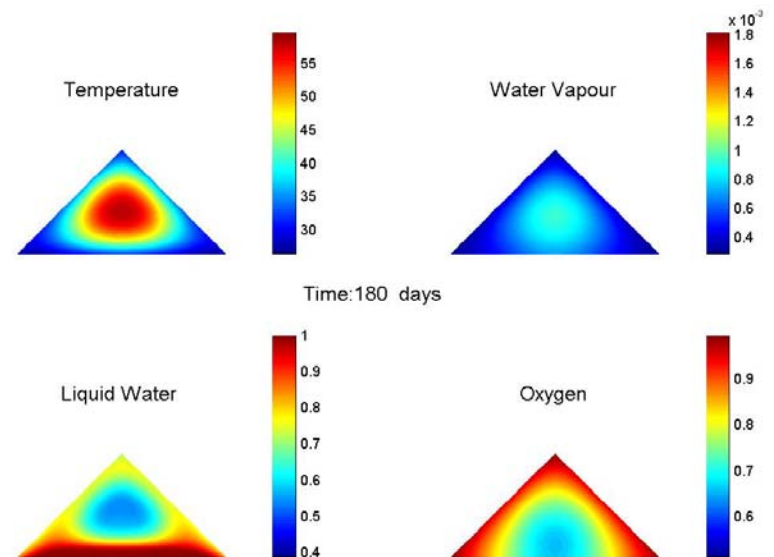
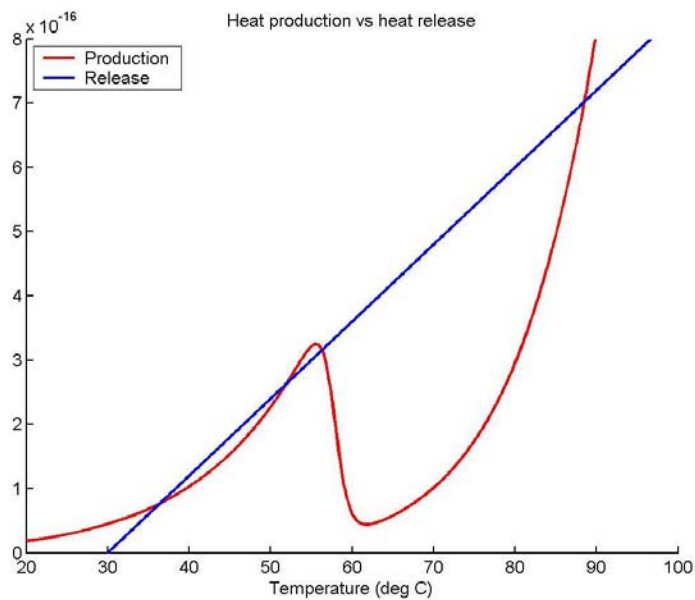
Modelling

- Heat generation: $\text{Exp}(-1/\text{Temperature})$
- Heat loss: Newtonian cooling; linear
- Bhopal example



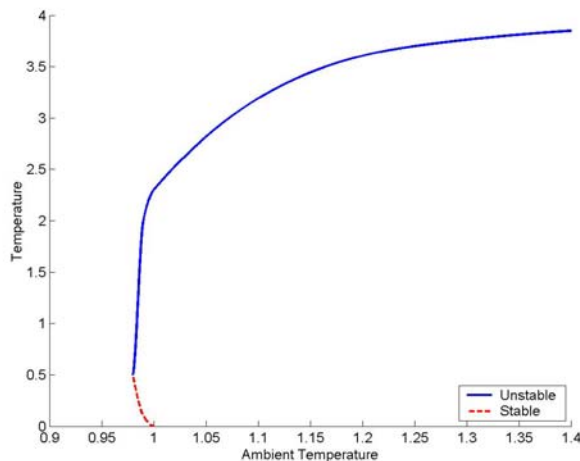
Modelling

- Bagasse
 - Geometry

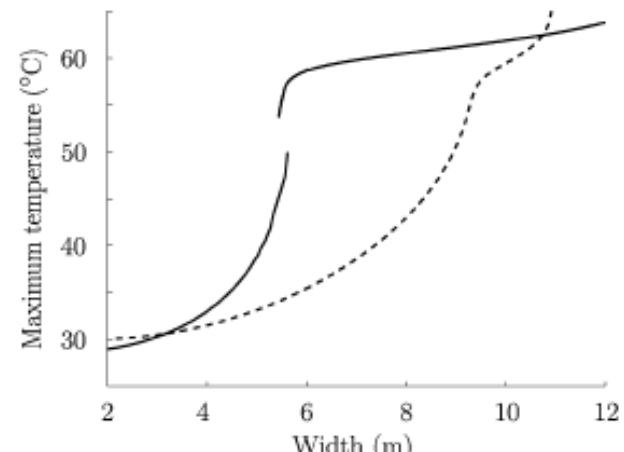


Dynamical Systems Theory

- Bifurcation analysis
- Bhopal: Ambient temperature
 - Stable regimes can yield high temperature excursions leading to an explosion



- Bagasse
 - Width
 - Ignition before turning point



Conclusions

- Safety/risk analysis
 - Sensitivity analysis = Bifurcation analysis
- Simple physical models
 - nonlinear
 - capture/simulate behaviour and give further insight
- Chemical reactor design and storage technology