Update on Activities in the Swanson Engineering Simulation Program

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Roadmap

- Objectives and desired outcomes
- Case-study approach
- Web-based instruction
- Experiential learning
- Simulation templates in a lab course
- Conclusions

Objectives

- To bring revolutionary enhancements to the mechanical engineering curriculum through the wise use of simulation technology
- To disseminate results widely so as to have a national impact.

Desired Outcomes

- Our graduates are well prepared to make the intelligent use of simulation technology
- The student learning experience is greatly enhanced by using simulation tools:
  - As virtual lab environments amenable to hands-on exploration
  - To make strong connections between theory and practice
  - To make abstract concepts more concrete
  - To analyze more realistic problems

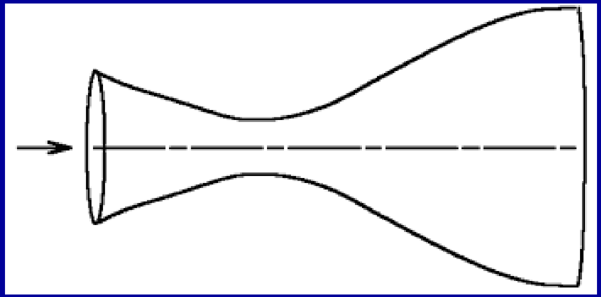
Approach

- Albert Einstein in essay *On Education:*
  - “I oppose the idea that the school has to teach directly that special knowledge and those accomplishments which one has to use later directly in life”
  - “If a young man has trained his muscles and physical endurance by gymnastics and walking, he will later be fit for every physical work”
- Emphasis: Imparting concepts rather than skills

Case Study Approach

- Apply simulation tools to solve canonical problems with analytical solutions or approximations
- Analogous to validation during code development
- Start with a simple example: eg. 2D static truss, laminar pipe flow etc.
- Gradually build up the complexity of the exercises

Example: Compressible Nozzle Flow

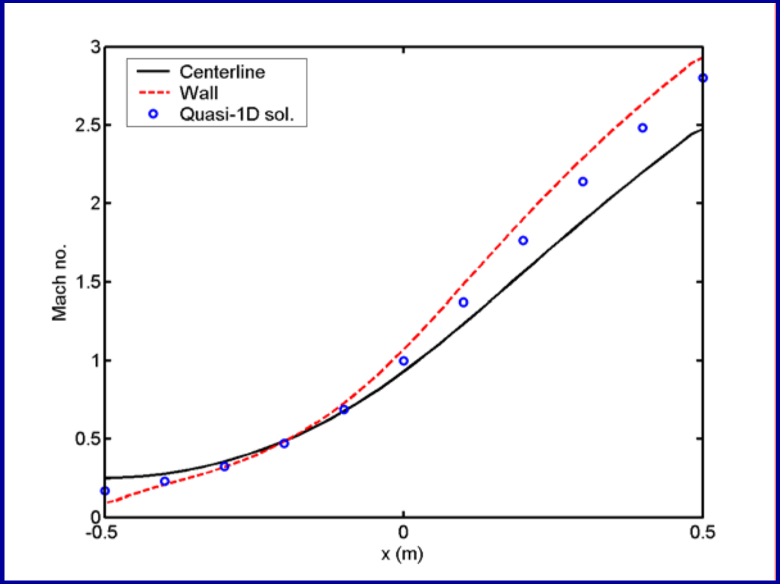


- High-speed flow through an axisymmetric converging-diverging nozzle
- Theory: Inviscid, quasi-1D analysis
  – Predicts operating regime based on $P_{o,in}/P_{exit}$
  – Isentropic solution: Gives Mach number, pressure, temperature variations

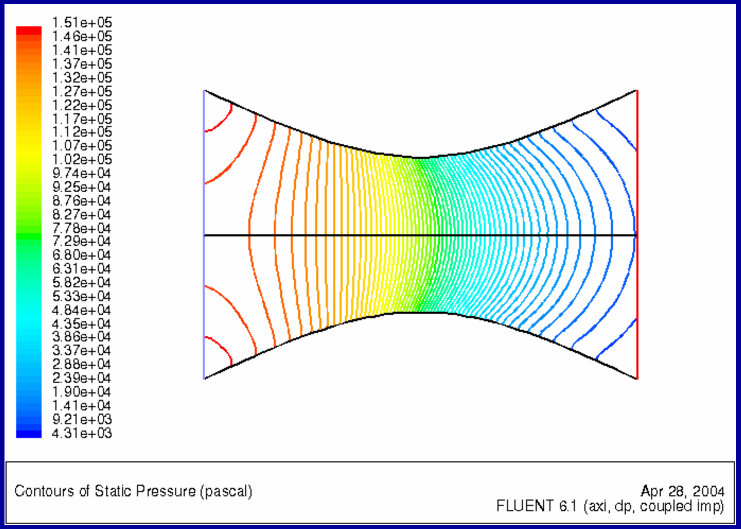
Example: Compressible Nozzle Flow

- Simulations: Axisymmetric, inviscid solution using FLUENT
- Isentropic, supersonic case: $P_{o,in}/P_{exit} = 27.1$

Mach No. Variation



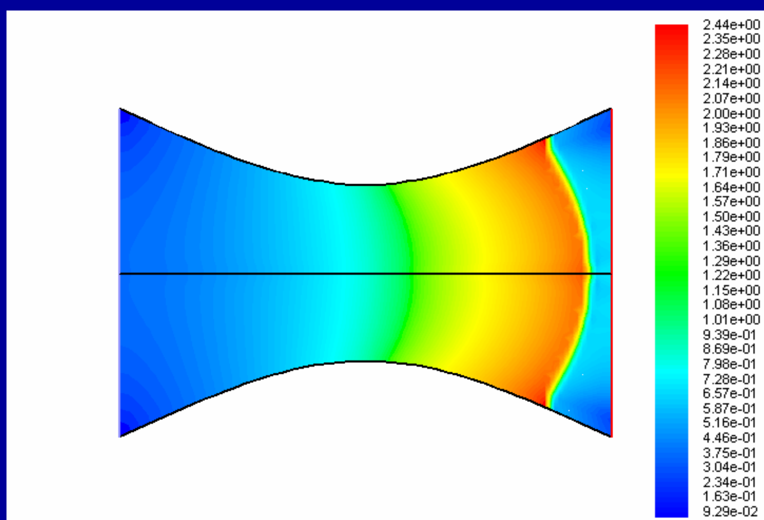
Pressure Contours



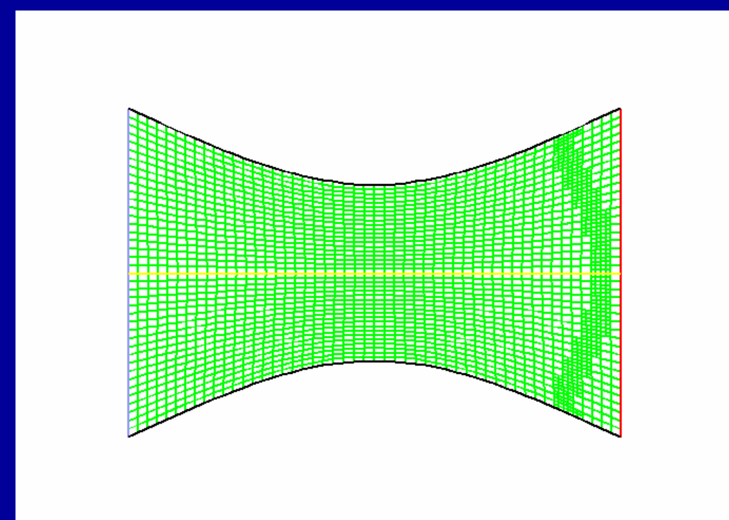
Example: Compressible Nozzle Flow

- Non-isentropic case: $P_{o,in}/P_{exit}=1.56$
- Quasi-1D analysis: Shock in the diverging section

Mach no. contours



Adapted grid



Case Study Approach

- Case studies used in *Intermediate Fluid Dynamics* course in spring 2004
  - Laminar developing flow in a pipe
  - Turbulent developing flow in a pipe
  - Flat plate boundary layer
  - Flow over a backstep
  - Compressible nozzle flow
  - Flow over an airfoil
- Student survey in 2003: 24/38 were favorable
- Design Project: Optimize wing performance

Case Study Approach

- Pedagogical philosophy used to introduce basic numerical concepts:
  - Illustrate each step in CFD solution process on simple 1D model equation on a small grid
  - Relate model problem concepts to general CFD solution process for each step
- Makes fundamental concepts more concrete than a verbal and graphical description
- Topics chosen were the minimum necessary for case studies: “Just-in-time” teaching

Web-Based Instruction

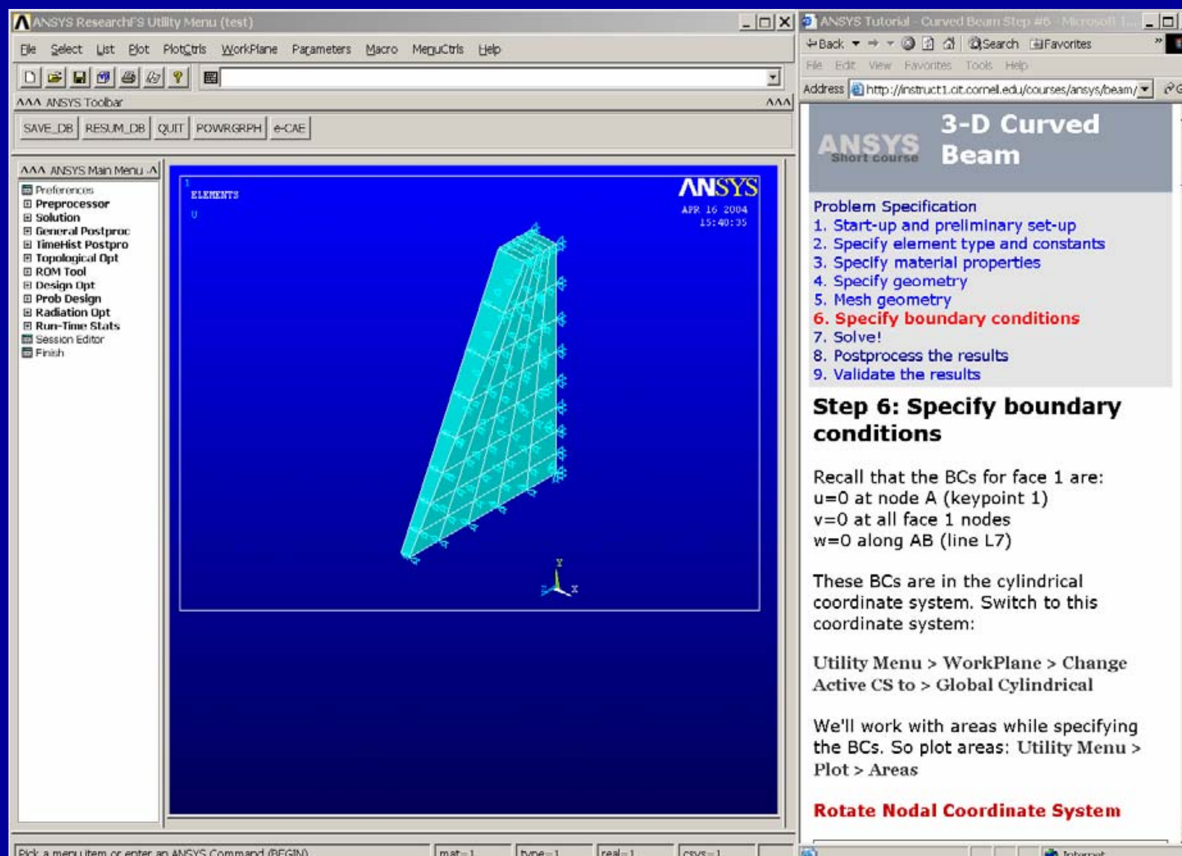
- Advantages of the web:
  - Reduces face-to-face time required for teaching the mechanics of using the GUI
  - Enables learning through self-paced, hands-on use
  - Convenient resource for students
  - Can give real-time feedback to the user
  - Material easier to update for newer versions of the software
  - Facilitates asynchronous learning

Web-Based Instruction

- Have continued developing web-based tutorials to teach the use of:
  - FEA simulations using ANSYS
  - CFD simulations using FLUENT

Web-Based Instruction

Arrangement of ANSYS and browser windows



Web-Based Instruction

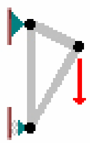
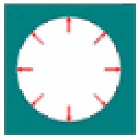
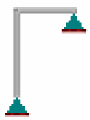
- As the user follows a tutorial and clicks away with the mouse, she is apt to lose track of the big picture
- Providing a structure to the learning experience is important
  - Each tutorial is broken down into the same steps
  - The list of steps appears at the top of each page of the tutorial
  - Current step is highlighted to track progress

Web-Based Instruction

- Challenge: To teach students to regard the results skeptically
  - Discourage blind acceptance of results that the computer spits out
  - Analogous to the pitfalls of the “formula mentality”
- Added a separate validation step to each tutorial

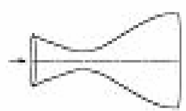
Web-Based Instruction

Basic ANSYS tutorials

	Two-Dimensional Static Truss
	Plate with a hole
	Vibration analysis of a frame
	Three-dimensional curved beam

Web-Based Instruction

Basic FLUENT tutorials

	Laminar Pipe Flow
	Turbulent Pipe Flow
	Compressible Flow in a Nozzle
	Flow over an airfoil

Web-Based Instruction

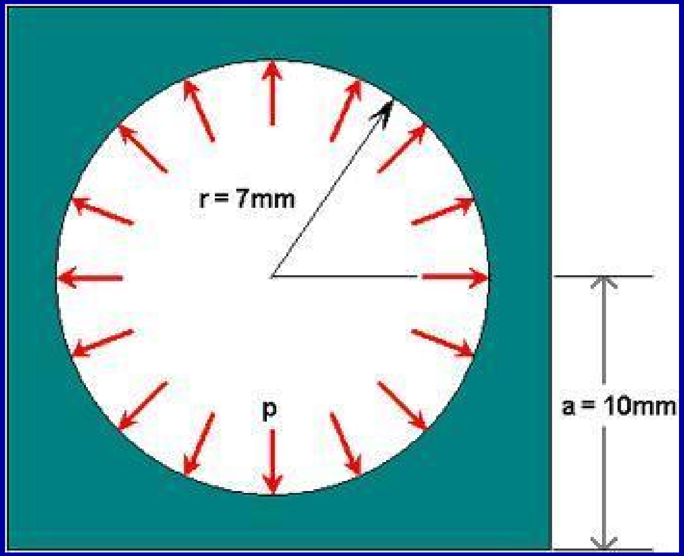
- Tutorial repository is being built-up through student M.Eng projects
- FLUENT tutorials:
  - Forced convection over a flat plate: Matthew Offerman
- ANSYS tutorials:
  - Contact analysis: Oswaldo Rodriguez
  - 2D orthotropic plate: Oswaldo Rodriguez
  - Structural and thermal analysis of a three-dimensional shell: Farid Kachra
  - Fracture analysis: Roberto Malvaez

Experiential Learning

- Modus operandi:
  1. Students go through the tutorial outside of class
  2. Follow-on hands-on sessions in the classroom/computer lab
- Hands-on sessions:
  - Tweak original problem and study how the solution procedure and results change
  - A very effective way to clarify and reinforce concepts

Experiential Learning

- Example :
  - Plate tutorial: Solve using 4-node quadrilateral elements



Experiential Learning

- Example (continued):
  - Hands-on session:
    1. Start from tutorial solution using 4-node quad
    2. Which of the nine tutorial steps need to be modified for the 8-node quad solution?

For instance, does the boundary condition specification step (step 6) have to be redone?

Opportune moment to discuss the difference between applying loads to the geometry or to the mesh

ANSYS Short course — **Plate with a Hole**

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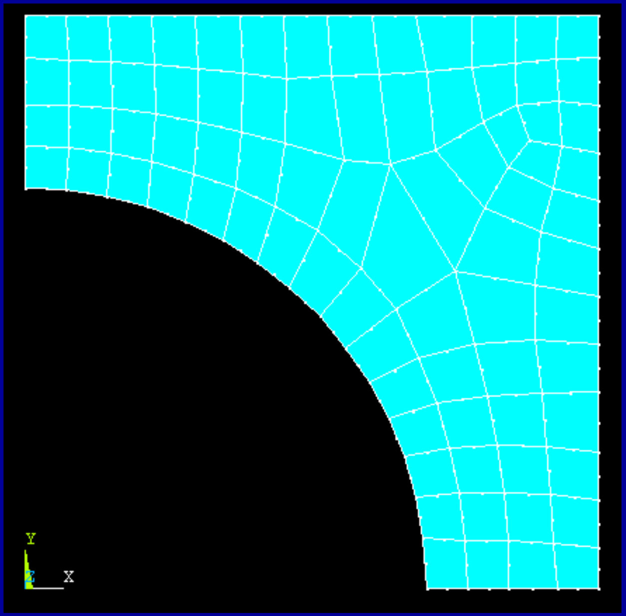
Problem Specification
1. Start-up and preliminary set-up
2. Specify element type and constants
3. Specify material properties
4. Specify geometry
5. Mesh geometry
6. Specify boundary conditions
7. Solve!
8. Postprocess the results
9. Validate the results

Problem Set 1

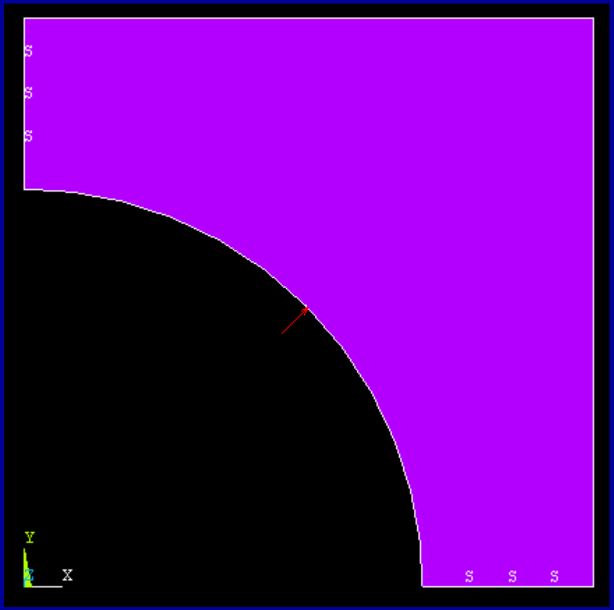
Experiential Learning

Remeshed Model

Element Model



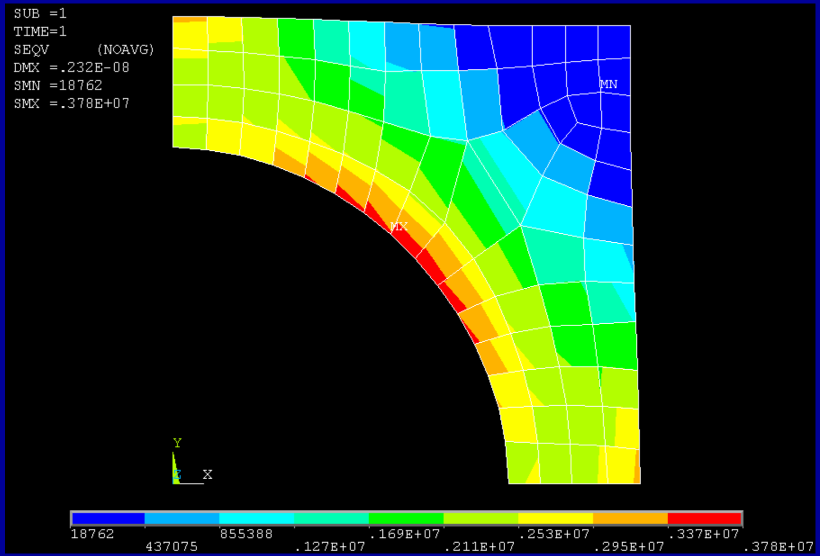
Geometry Model



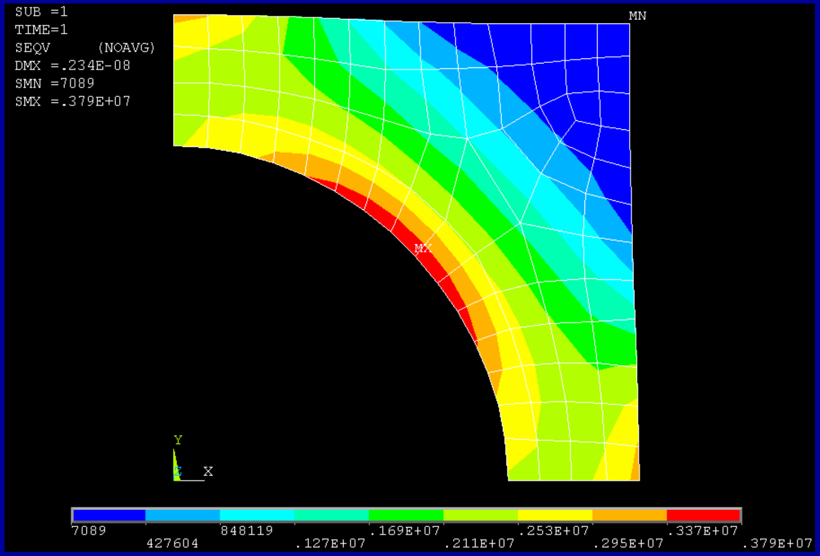
Experiential Learning

- Example :
  - Hands-on session (continued):
    3. Compare the element solutions for the two cases

Four-node quad



Eight-node quad



Experiential Learning

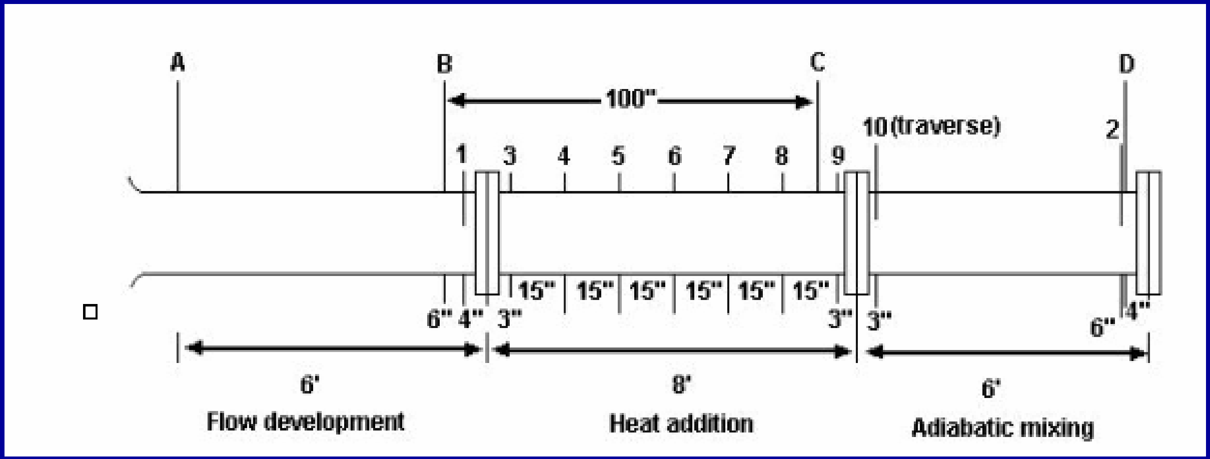
- Wallace & Weiner (1998):
  - Computer-based experiential learning more effective than traditional lecture-based learning
  - Hands-on exercises provide extra motivation for students to participate in learning in the classroom
- Combination of simulation and web technologies enables a new and more effective way of teaching

Simulations in a Lab Course

- *FlowLab:* Problem-specific front end to *FLUENT*
- Approach:
  - Perform simulation corresponding to experiment
  - Compare experimental and simulation results
- Template development supported by NSF
- Partners: Univ. of Iowa, Iowa State Univ., Howard Univ. and Fluent Inc.

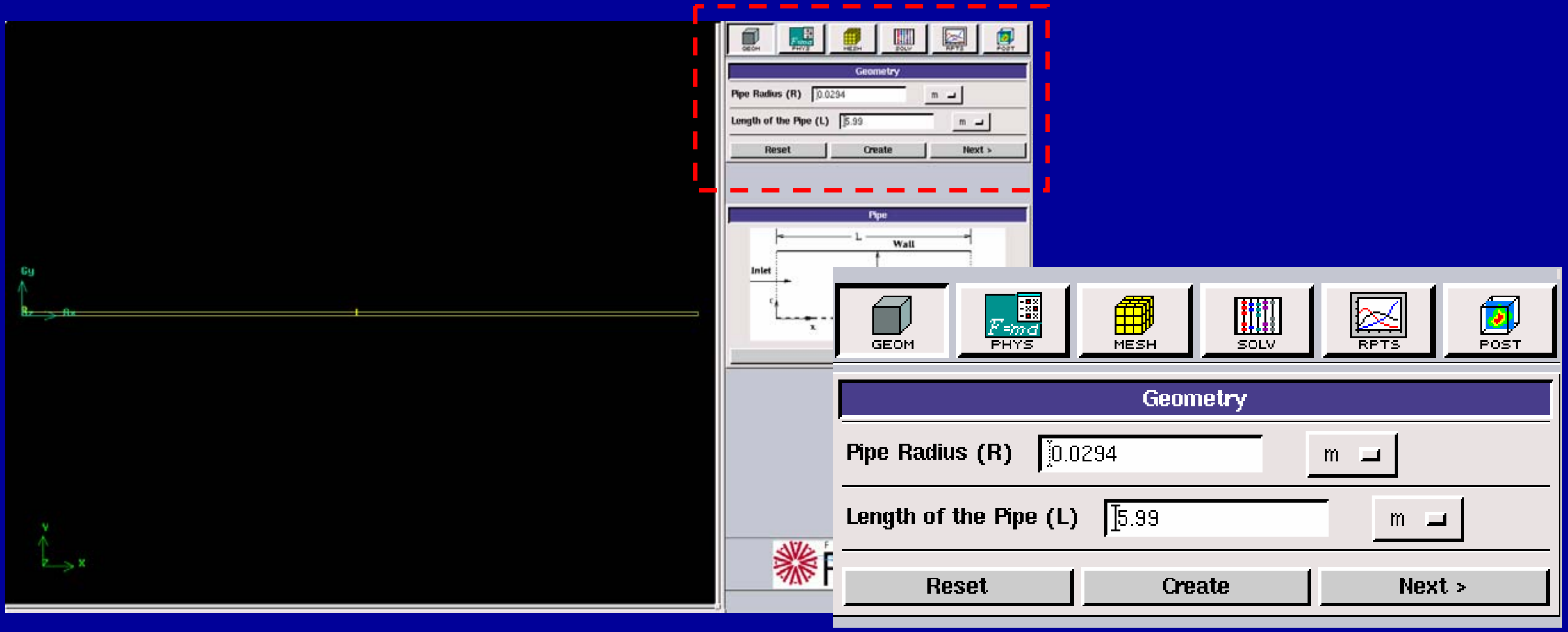
Heated Pipe Flow Experiment

- Raw measurements: Wall and gas temperatures; pressure drops; power to heater
- Determine friction factor & Nusselt no.



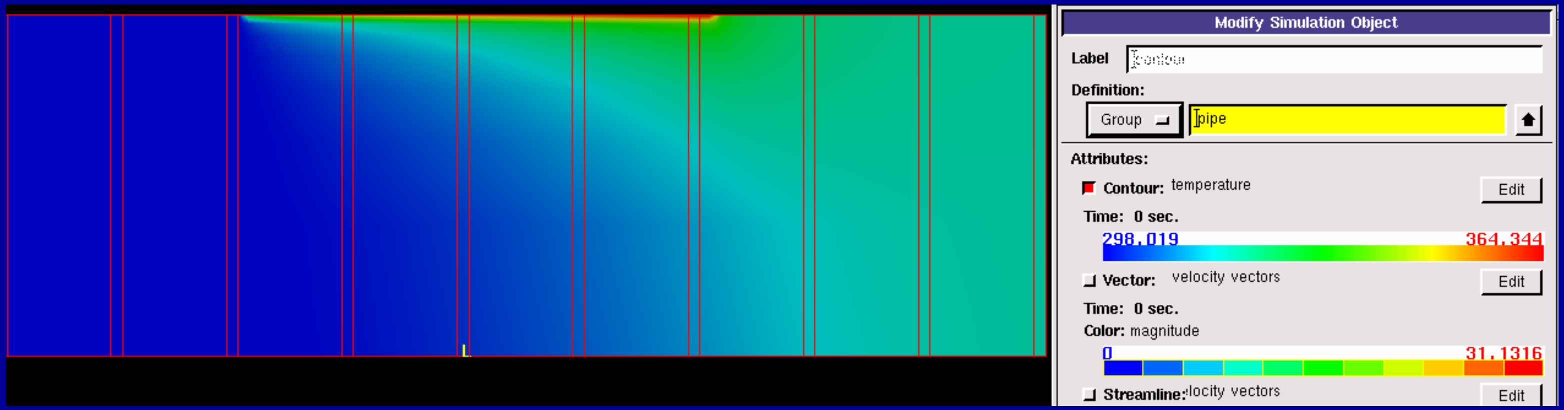
Heated Pipe Flow Experiment

FlowLab Interface



Heated Pipe Flow Experiment

FlowLab output: Temperature contours



Heated Pipe Flow Experiment

	Experiment	Correlation	Numerical Simulation
Reynolds number	100820	input	input
Friction factor	.0180±.003	.0177	.0168
Nusselt number	185	183	192

Heated Pipe Flow Experiment

- Students gain:
  - Physical understanding of the experimental system that is hard to get from a few point measurements.
  - Confirmation of some aspects of the data processing for the experiment (e.g. that mixing region is long enough).
  - Confirmation of experiment and correlation.

Conclusion

- Cornell President Jeff Lehman's "Call to Engagement":
  - How should we be teaching? Have new technologies and research on how students learn created possibilities for better pedagogy, or are they mere distractions?
- Better pedagogy is possible through case studies, web-based instruction, experiential learning and problem-specific simulation templates

Conclusion

- Emphasis is on:
  - Understanding of the solution procedure
  - Analysis and validation of results
  - Concepts rather than skills
  - Making connections between fundamental concepts and simulation
  - Explaining abstract concepts through visual aids