Work in Progress – A Web-Based Virtual Supersonic Nozzle Module as a Visualization and Active Learning Tool for the Undergraduate Thermodynamics Course

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Abstract - A web-based visualization tool has been developed and used for teaching undergraduate students about flow and thermodynamic property variations in isentropic (shock-free) and non-isentropic (normal shock embedded) one-dimensional compressible flows in nozzles. The web-based module simulates these flow regimes by numerically solving conservation laws for mass, momentum and energy, and enables real time visualization of results using an animation program. The module through its interactivity feature permits students to change operating pressure conditions to visualize flow property variations inside a supersonic nozzle by clicking and dragging action of a computer mouse. The module through a variety of visual images of physical phenomenon also provides student the engineering context of underlying engineering principles and governing equations.

Index Terms - Visualization, Simulation, Web-Based Resources, Interactive Learning

INTRODUCTION

Visualization and simulation technologies are being used in many key industries such as aircraft, automotive and consumer products. These technologies have matured to a point that they can and should be integrated as learning tools into engineering curricula. These technologies have enormous potential for creating paradigm changes in the way engineers of the future will be educated and trained. The current engineering students are becoming very adept to a learning style based on visualization, primarily due to their familiarity with computers, the internet and interactive video games, and this fact is becoming an important factor in the transformation of engineering education. Recent advances in computer technologies are providing exciting opportunities to engineering educators to help transform the learning process from the conventional mode of teacher-centric to the student-centric mode through the use of web-based resources. In order to facilitate transformation of engineering courses to visualization enhanced courses, the senior author applied for and received a National Science Foundation grant titled “Planning Grant: Simulation and Visualization Enhanced Engineering Education.” As a result of this ongoing grant, the authors have developed a web-based module involving the operation of a virtual supersonic nozzle. This module has been incorporated in the Thermodynamics II (ME 312) course which deals with application of thermodynamic laws to real life problems such as high speed flows and combustion. The primary objective of the module is to teach students, using interactive visualization and simulation tools, about property variations in isentropic (shock-free) and non-isentropic (normal shock embedded) flows in nozzles and diffusers.

The module has two distinct features. First, it promotes active learning through a user friendly and interactive modular design. This feature is expected to transform students from a passive to active fully-engaged learners. Secondly, the module is designed to provide students practical context by including a variety of applications and phenomena involving subsonic and supersonic nozzles in jet engines and rockets. This is done by collecting and organizing video images as well as text materials that familiarizes students with physical aspects and application of high speed flow in nozzles.

WEB-BASED MODULE STRUCTURE

The web-based supersonic visualization module (www.mem.odu.edu/shockwave), developed by authors, is organized in four parts. The “Analysis Module” presents basic concepts, engineering principles and governing equations. The “Physical Module” displays video-images as well as configuration data for a variety of nozzles used in rockets, space shuttles and high speed planes. The “Simulation Module” provides results involving isentropic and normal...
shock flow regimes obtained from the Computation Fluid Dynamics (CFD) code “Fluent” [3]. The “Interactive Visualization Module,” the heart of this web-based tool, permits students to operate the nozzle in the virtual domain by specifying upstream (stagnation) and back pressure conditions. The primary objective of this module is to introduce students visually to isentropic and normal shock flow phenomena in supersonic nozzles. By changing the back pressure, students are able to explore conditions under which normal shock will occur in the diverging section of the nozzle. Furthermore, they are able to explore how the shockwave will move through the nozzle as the back pressure is changed.

In order to demonstrate variation of thermodynamic and flow properties in the nozzle, a novel method of using the clicking action of a computer mouse is used. As the mouse is clicked at a chosen point in the flow field, a box appears, detailing the properties such as temperature (T), pressure (P), Mach number (M), flow velocity (V), speed of sound (C), density (d), area ratio (A), stagnation temperature (T_o) and stagnation pressure (P_o). By clicking and dragging action of the mouse along the nozzle axis, students can readily observe variation of these flow properties in the flow direction, as well as at locations just upstream and downstream of a normal shockwave which is visually indicated in the module.

**CONCLUSION AND FUTURE WORK**

The web-based visualization module has been introduced in the Thermodynamics II class during the Spring 2005 semester as a tool to supplement conventional classroom teaching. The four learning outcomes, developed for the module, are being assessed to determine the effectiveness of the module in enhancing students understanding of physical phenomena related to high speed flows in nozzles and diffusers. The future plan includes full integration of the module in lecture classes in mediated classrooms with Internet access. The module will also be used in future for student projects involving calculation of nozzle thrust with altitude.

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**REFERENCES**

