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COMPUTATIONAL FLUID DYNAMICS (CFD) OF CHEMICAL OXYGEN/IODINE LASER (COIL) FLOWFIELDS

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THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

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14. ABSTRACT
This report describes an overview of the research efforts undertaken to develop a computational fluid dynamics (CFD) tool to analyze flowfields relevant to chemical oxygen/iodine lasers (COIL). In the listed references, computations of the three-dimensional nozzle flowfields with transverse jet injection are described, in addition to several two-dimensional computational results, verifying the implementation of the model equations. Improvement in the efficiency of the computations was demonstrated by the use of a grid sequencing approach.

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1. BACKGROUND

The chemical oxygen/iodine laser (COIL) has been studied as a possible weapon system since its invention in 1978. Before an operational weapon system can be developed from COIL technology, the physical processes characterizing the COIL need to be understood. Accurate modeling of these processes within COIL devices is very difficult because of the complex phenomena that are present. It is common to employ simplifying approximations when modeling these flows. Relying on such approximations leaves open the possibility key physical processes are not being accurately modeled and erroneous conclusions can be made as a result. Because of the small (cm) length scales of these systems, detailed experimental data within the flowfield of the laser device is extremely sparse. Other than measuring power output of the laser beam, there is little data with which to substantiate analytical or computational methods used to predict laser performance during operational conditions. Therefore, there is a tremendous need for computational tools to provide the key understanding of flowfields within COIL devices.

This in-house research project was initiated to develop a validated COIL analysis capability. The project combined experimental and computational simulations of internal gas dynamics with transverse injection in order to verify the scientific findings. Sponsorship was provided by the U.S. Air Force Research Laboratory's Office of Scientific Research (AFOSR) as part of an Entrepreneurial Research Initiative over the period July 1999 through 30 September 2003. Funding for this in-house research activity ended in fiscal year 2002 and a DoD High Performance Computing Challenge Project was initiated with AFRL/DE in FY03.

2. APPROACH

A primary objective of the research effort was the development of a computational simulation capability for COIL. Verification and validation of this capability was performed by correlations of computational results with experimental data obtained in path-finding ground tests. By combining the interdisciplinary expertise areas of chemical kinetics, aerodynamics, and parallel processing, the computational code developed has evolved into a practical simulation tool to study complex physical processes within COIL flowfields, such as unsteadiness, three-dimensional mixing, and shock-dominated flows.

Overall, the project consisted of the following three phases:

1. Validation of the nonreacting flowfield within the nozzle/injector system. The validation of the baseline flow solver was performed by comparison with two sets of experimental data provided by AFRL/DE. The flowfield conditions were representative of typical jet penetration conditions observed during optimum operation of the COIL. The computational results agreed well with measured mass flow rates and wall pressure data.
2. Development of the computational capability using unstructured technology and continued validation by comparison with measurements of small signal gain. The computations performed during this phase utilized the full three-dimensional reacting flow capability of the new CFD solver. Computational results were compared with very limited experimental data and it was determined that the results were very sensitive to the chemical kinetics model employed. In addition, large-scale unsteadiness was discovered for the two-dimensional case.
3. Finally, more detailed validation and verification studies were performed by comparison with experimental data and code-to-code comparisons with the GASP code (version 4) and the AFRL/DE version of GASP. The focus of these detailed validation studies was to build confidence in the computational capabilities and understand the mechanisms of unsteadiness within COIL devices.

3. RESULTS

The flow solver developed from this research has been utilized to better understand the mechanisms of unsteadiness within COIL devices. In addition, the results obtained as part of this research helped to establish several baseline test cases to be used in future validation studies for ongoing development efforts of COIL models. Details of the research results can be found in the references listed in the Bibliography.

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