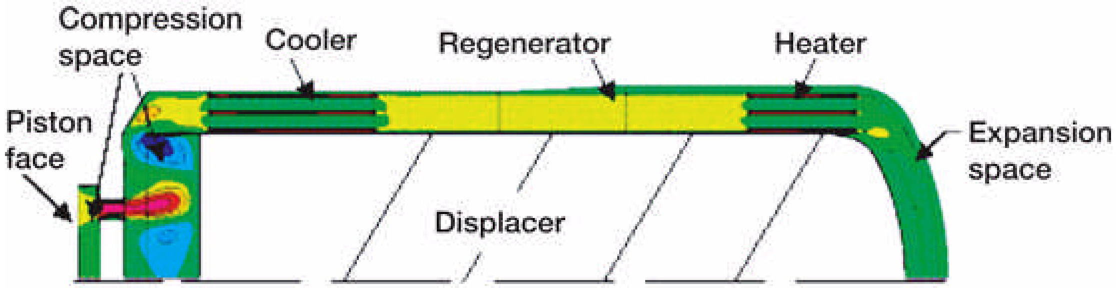
NASA Multidimensional Stirling Convertor Code Developed

A high-efficiency Stirling Radioisotope Generator (SRG) for use on potential NASA Space Science missions is being developed by the Department of Energy, Lockheed Martin, Stirling Technology Company, and the NASA Glenn Research Center. These missions may include providing spacecraft onboard electric power for deep space missions or power for unmanned Mars rovers. Glenn is also developing advanced technology for Stirling convertors, aimed at substantially improving the specific power and efficiency of the convertor and the overall power system. Performance and mass improvement goals have been established for second- and third-generation Stirling radioisotope power systems. Multiple efforts are underway to achieve these goals, both in house at Glenn and under various grants and contracts. These efforts include the development of a multidimensional Stirling computational fluid dynamics code, high-temperature materials, advanced controllers, an end-to-end system dynamics model, low-vibration techniques, advanced regenerators, and a lightweight convertor.



Schematic showing velocity contours generated by a two-dimensional axisymmetric CFD-ACE model of a Stirling convertor working space.

Under a NASA grant, Cleveland State University (CSU) and its subcontractors, the University of Minnesota (UMN) and Gedeon Associates, have developed a two-dimensional computer simulation of a CSUmod Stirling convertor. The CFD-ACE commercial software developed by CFD Research Corp. of Huntsville, Alabama, is being used. The CSUmod is a scaled version of the Stirling Technology Demonstrator Convertor (TDC), which was designed and fabricated by the Stirling Technology Company and is being tested by NASA. The schematic illustrates the structure of this model. Modeled are the fluid-flow and heat-transfer phenomena that occur in the expansion space, the heater, the regenerator, the cooler, the compression space, the surrounding walls, and the moving piston and displacer. In addition, the overall heat transfer, the indicated power, and the efficiency can be calculated. The CSUmod model is being converted to a two-dimensional model of the TDC at NASA Glenn.

Validation of the multidimensional Stirling code is an important part of the grant effort. UMN has been generating data in an oscillating-flow test facility using two different test sections: a 90° turn and a cooler/regenerator/heater test section. CSU has created computational fluid dynamics models of both these test sections and has been making comparisons with the data, then improving their models to improve the agreement with the test data. CSU has also been using data available in the literature for code validation. UMN is now preparing to begin fabrication of a new 180° turn test section that will be more representative of certain portions of the Stirling engine geometry.

Simulations to almost periodic steady state with the two-dimensional CSUmod model indicate that, to reach periodic steady state on a single 2-GHz desktop computer, 75 to 100 complete simulation cycles would be required and between 1 and 2 months of computer time. Therefore, Glenn has purchased the first 8 computers, of a 64-computer cluster, to be run in parallel to accelerate the simulation. On the basis of CFD Research Corp.'s experience with running the parallelized version of CFD-ACE on their clusters, we estimate that the complete 64-computer cluster will reduce simulation computing time by a factor of about 40.

Plans are to continue development of these multidimensional Stirling codes and to use them to study the fluid-flow and heat-transfer phenomena that occur inside Stirling convertors. This is expected to lead to improved thermodynamic loss understanding, one-dimensional design and performance codes, and engine performance.

Find out more about this research: http://www.grc.nasa.gov/WWW/tmsb/stirling.html

Glenn contacts: Dr. Roy C. Tew, 216-433-8471, Roy.C.Tew@nasa.gov; and Lanny G. Thieme, 216-433-6119, Lanny.G.Thieme@nasa.gov
Sest, Inc., contact: Scott D. Wilson, 216-433-6681, Scott.D.Wilson@grc.nasa.gov

Authors: Dr. Roy C. Tew and Lanny G. Thieme
Headquarters program offices: OAT, OSS
Programs/Projects: Energetics, Prometheus, SRG