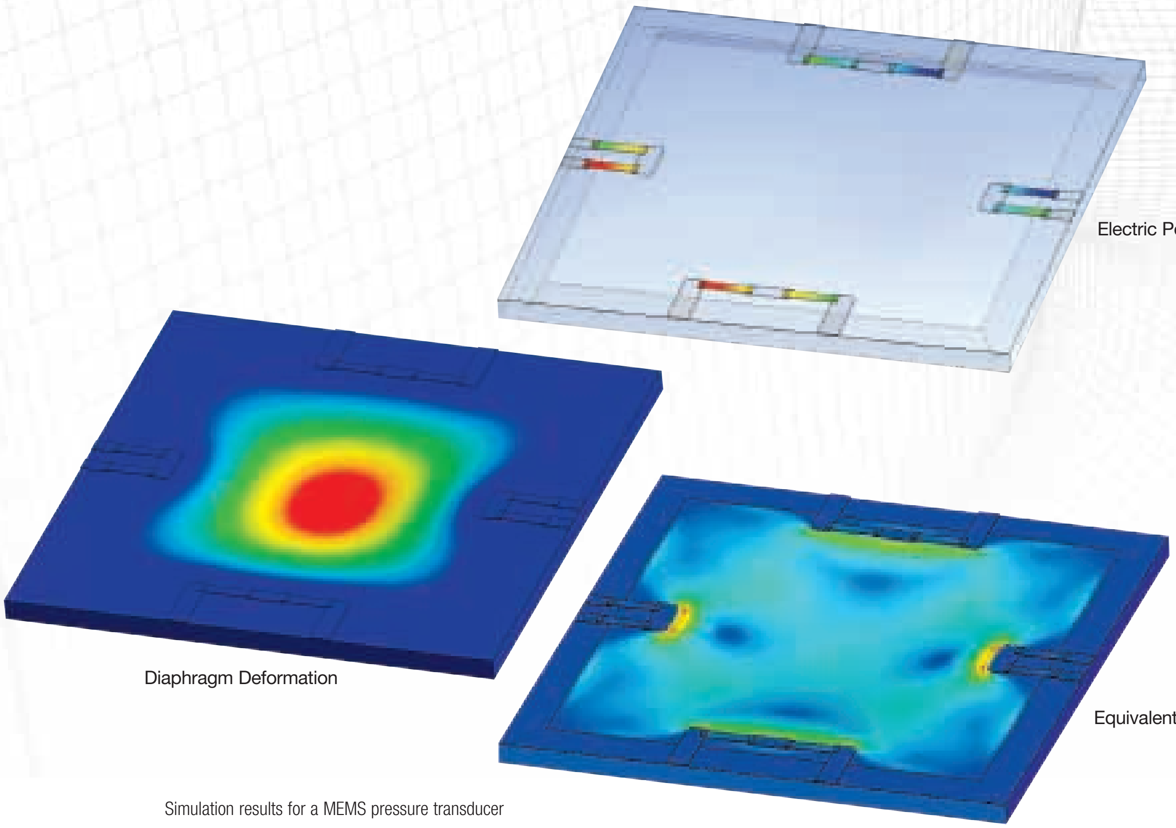


Simulation results for a MEMS pressure transducer

Multiphysics in Action

Powerful coupled-physics simulation tools solve demanding applications in a wide range of industries.

By Stephen Scampoli, Multiphysics Product Manager, ANSYS, Inc.

In an expanding range of applications, engineers must be able to accurately predict how complex products will behave in real-world environments in which multiple types of coupled physics interact. Multiphysics simulation is becoming crucial in the development processes for a rapidly growing number of companies. It has the potential to influence engineering simulation efforts in coming years, as more and more companies recognize the strategic value of the technology.

The increased demand for multiphysics simulation is occurring in many different industries as companies strive to maintain a competitive edge. In the electronics industry, high current densities in microchip circuits create large heat loads that need to be dissipated. In the automotive industry, airflow over exterior components, such as side-view mirrors, can create unwanted noise and vibration. In the bio-medical industry, understanding how blood flows through stent grafts can be used to improve surgical procedures. In these and a growing number of other applications, multi-physics simulation is rapidly becoming a competitive necessity by allowing engineers and designers to closely evaluate their designs under real-world operating conditions.

Advanced Technology

Multiphysics simulation has been part of the core technology from ANSYS for several decades. From the early versions of the software that included thermal–stress calculations to the recent development of complex thermo-electric–fluidic calculations, ANSYS solver technology has continued to advance the development of state-of-the-art multiphysics solution capabilities.

The functionality of multiphysics technology from ANSYS is unparalleled, with no other solution provider able to match the long development history and the technical depth of solution capabilities. Indeed, companies needing true "industrial strength" multiphysics capabilities continue to rely on the complete repertoire of industry-leading functionality from ANSYS.

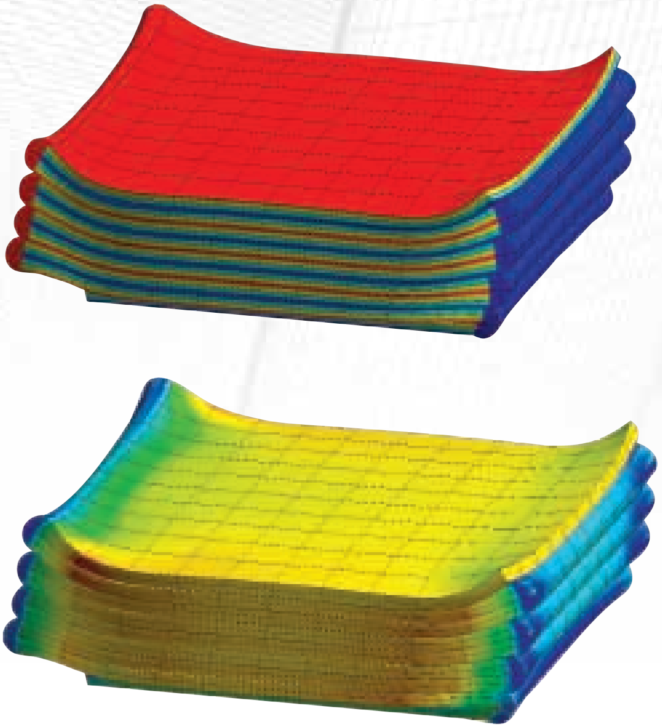
The current version of ANSYS Multiphysics software has two proven solution techniques for solving coupled-physics problems — directly coupled-field elements and the ANSYS Multi-field solver. These approaches provide flexible simulation methods built on proven solver technology to solve a broad range of complex coupled-field problems, such as induction heating, electrostatic actuation, Joule heating and fluid structure interaction (FSI).

Directly Coupled-Field Elements

Directly coupled-field elements allow users to solve coupled-physics problems by employing a single finite element model with the appropriate coupled-physics options set within the element itself. ANSYS coupled-field elements account for coupled physics by calculating the appropriate mathematical terms that include the interaction between the different physics disciplines. In this way, coupled-field element solutions simplify the modeling of a multiphysics problem by allowing users to create, solve and post-process a single analysis model for a comprehensive array of multiphysics problems.

ANSYS coupled-field elements encompass a wide variety of multiphysics analyses including thermal–structural coupling, piezoelectricity, piezoresistivity, the piezocaloric effect, the Coriolis effect (the apparent deflection of moving objects from a straight path when they are viewed from a rotating frame of reference), electroelasticity, thermal–electric coupling and thermal–electric–structural coupling. The broad range of capabilities provided by these elements is essential for the design of many products, such as electronic components, micro-electro-mechanical systems (MEMS), transducers, piezoelectric gyroscopes, accelerometers and thermoelectric coolers.

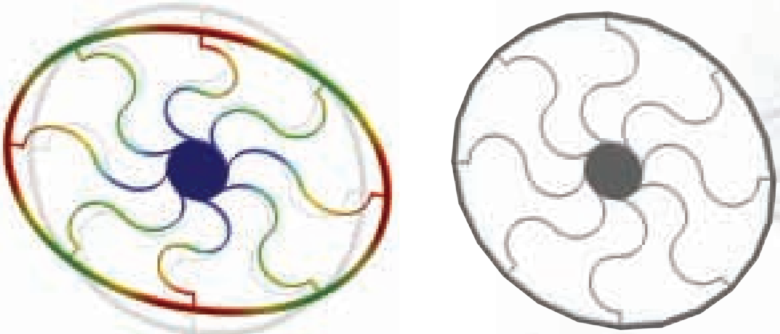
In one such application, ANSYS coupled-field elements were used to evaluate the performance of a vibrating silicon ring gyroscope, a particular type of angular velocity sensor



Electric potential (top) and equivalent stress (bottom) simulation results for a folded dielectric elastomer actuator

commonly used in automotive braking systems and vehicle stability control systems. The gyroscope is a solid-state device comprising a micromachined silicon ring suspended by surrounding spokes. The ring is excited into a primary mode of vibration and rotated while vibrating, setting up a secondary mode of vibration generated from the Coriolis effect. The angular velocity of the sensor is then detected by sensing the secondary mode of vibration, which is proportional to angular velocity.

One challenge in the design of silicon ring gyroscopes is minimizing energy loss for better sensor performance and lower power consumption. One of the most important

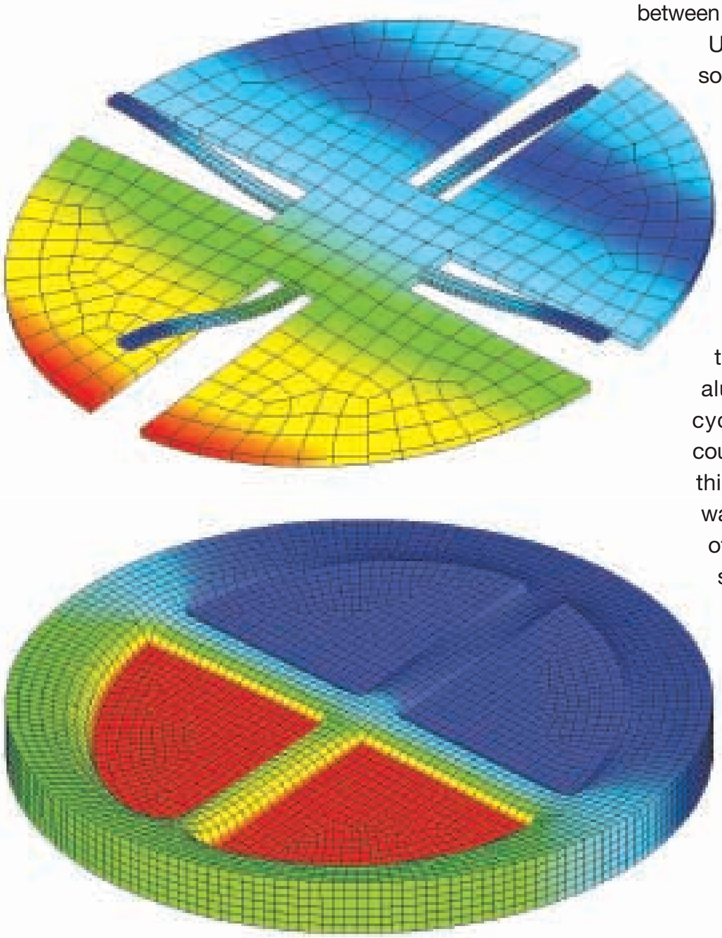


Analysis of the harmonic response of micromachined silicon ring gyroscope, including the effects of thermoelastic damping
Photo courtesy Silicon Sensing Systems Ltd., www.siliconsensing.com

energy-loss characteristics to be evaluated in the development of the device is thermoelastic damping arising from the irreversible heat flow across the temperature gradients induced by the strain field. This effect is characterized by a strong coupling between the structural and thermal fields, accurately represented using matrix coupling in ANSYS Multiphysics software. In this way, the software enabled engineers to minimize energy loss in the gyroscope by evaluating complex mode shapes and the harmonic response of the silicon ring gyroscope while accounting for thermoelastic damping.

Multi-Field Solver

The ANSYS Multi-field solver solves a wide variety of coupled-physics problems by employing implicit sequential coupling. Examples include thermal–structural coupling, thermal–electric–magnetic coupling, electromagnetic–structural coupling and fluid structure interaction (FSI).



The switching speed and positioning of a MEMS digital micromirror was studied by sequentially coupling the analysis of models for structural deformation (top) and electrostatics (bottom).

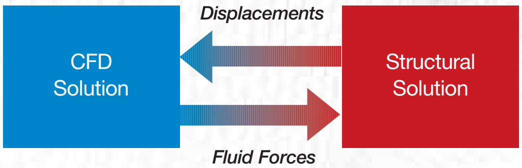
With sequential coupling, each physics discipline is solved sequentially, and results are passed as loads from one physics discipline to another with convergence between the individual physics disciplines obtained at each point during the solution. This robust convergence behavior of implicit coupling ensures accuracy and minimizes the engineering time needed to achieve valid simulation results.

Since two or more single-physics models are used within the ANSYS Multi-field solver, results can be passed across a dissimilar mesh interface between the physics disciplines. This is a subtle but very important consideration, since a dissimilar mesh interface allows a user to optimize the mesh for each individual physics discipline. For example, in a fluid structure interaction problem, the meshing requirements for the fluid are often different from those for the structure. A dissimilar mesh interface also allows independent users to set up their specific physics disciplines, which in turn allows for closer collaboration between physics experts.

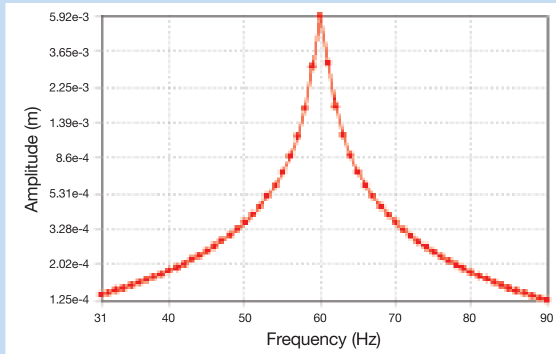
Using such an approach, the ANSYS Multi-field solver was used to evaluate the switching speed of a digital micromirror, a commercially successful MEMs device used as the basis of Digital Light Processing (DLP) technology. In a DLP projector, a projected image is created by an array of several hundred thousand digital micromirrors that each alternate rapidly between on and off states, projecting light from the projector into a lens that focuses the pixels on the screen. Held in place by thin tethers, the tiny aluminum mirrors are repositioned during each cycle using electrostatic forces. By sequentially coupling electrostatics and structural deformation in this complex problem, ANSYS Multiphysics software was instrumental in evaluating the positioning of the digital micromirror as well as the switching speed of the system.

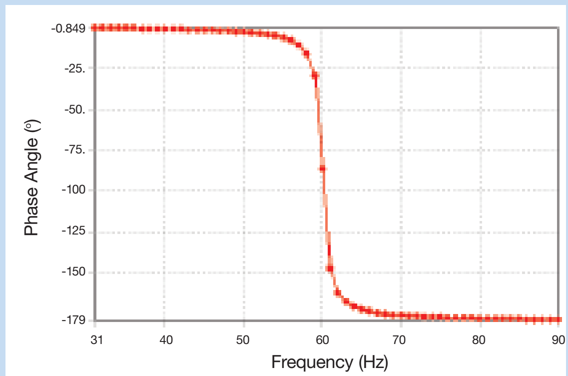
Another common application of the ANSYS Multi-field solver is fluid structure interaction, which occurs when a fluid interacts with a solid structure causing deformation in the structure and thus altering the flow of the fluid itself. An FSI solution is required for many industrial applications, such as the aerodynamic flutter of airplane wings, transient wind loads on buildings, and biomedical flows involving compliant blood vessels and valves.

For cases such as these, both the structural and fluid solutions must be run concurrently with loads transferred between the two solvers. ANSYS Multiphysics software provides a unique



Implicit coupling for fluid structure interaction includes iterative analyses of fluid forces that may cause structural reactions, which in turn may alter fluid flow.





implicit coupling scheme between these two solutions, in which no third-party coupling software is required, and each solution is able to run on a separate computer.

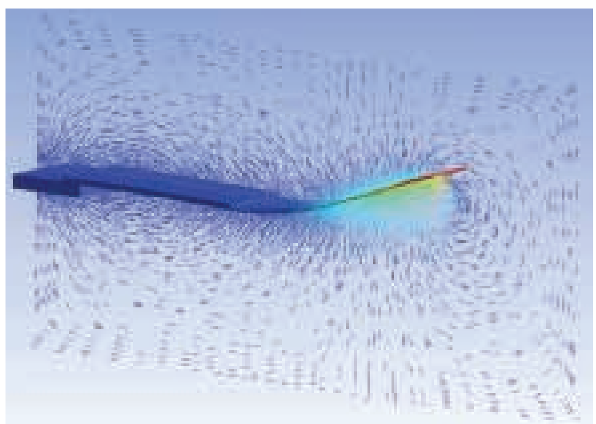
Another unique capability of the ANSYS Multi-field solver is the ability to include coupled-field elements within an FSI solution. In one project, coupled-field elements were used in conjunction with the ANSYS Multi-field solver to evaluate the performance of a piezoelectric fan in which the motion of the fan blade is generated by applying a voltage to a piezoelectric material. Often used for spot cooling of electronic components, piezoelectric fans typically consume less energy than conventional fans and do not produce electro-magnetic noise that can interfere with computer circuits.

In this device, the fan blade is driven at resonance using a standard AC excitation of 120 volts applied at 60Hz. ANSYS Multiphysics software was used to optimize the size of the fan blade to produce a resonant frequency of the device exactly at 60 Hz and to evaluate the motion of the fan blade and subsequent air flow. This solution required piezoelectricity to be coupled to computational fluid dynamics, which is a unique capability of ANSYS Multiphysics software.

Multiphysics as a Strategic Tool

By using such capabilities, engineers can now perform multiphysics analysis as a routine part of product development. In this way, coupled-physics simulation takes on strategic value in the development of virtual prototypes by accounting for all of the relevant physical phenomena that influence designs.

ANSYS continues to lead the industry in the development of multiphysics solutions that provide the high-fidelity simulations required to meet the challenges of today's demanding product development requirements. ■



ANSYS Multiphysics software was used in optimizing a piezoelectric fan blade geometry to produce a resonant frequency exactly at 60 Hz and in evaluating the motion of the fan blade and resulting air flow.