Quest for the 200-mpg Car

A revolutionary internal combustion engine gives rise to a supermileage vehicle with the potential to transform automotive design.

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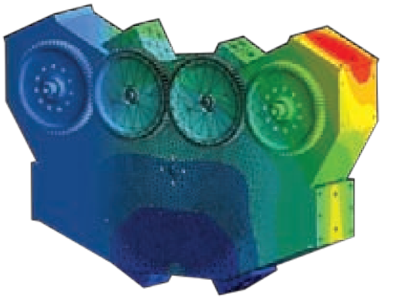
The N-R 1 supermileage vehicle is expected to perform at an extremely high level of efficiency: transporting four adults 200 miles at 70 miles per hour on only one gallon of fuel. This vehicle and its engine, part of the revolutionary family of high-efficiency Centrifugal Heinz Boxer (CHB) engines, are being developed by Niama-Reisser, LLC, in the United States.

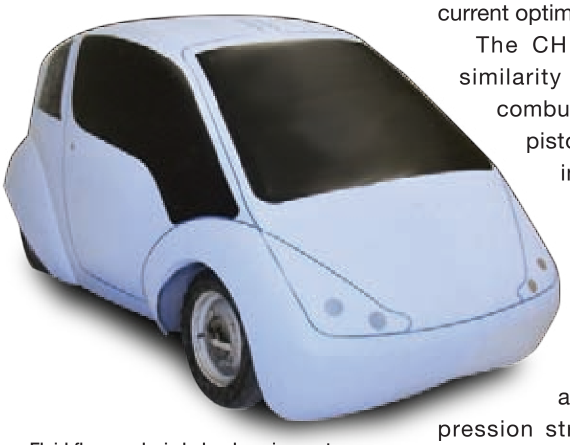
Niama-Reisser is a vehicle and propulsion service company with a dedicated engineering department specializing in consulting, research and development of internal combustion engine design, major subsystems and entire vehicles. Utilizing ANSYS FLUENT software for fluid flow and ANSYS Mechanical technology for structural and thermal simulations, the company offers a wide range of services for custom engineering projects. It also conducts ongoing research and development projects on innovative concepts.

Prototype CHB engine attains high efficiency with on-the-fly adaptive compression ratio, engineered composite material components and fewer parts.



Stress distribution of the CHB engine housing overlaid on the geometry and mesh of the ANSYS Mechanical model

In developing the supermileage vehicle, engineers used ANSYS FLUENT software to determine drag coefficient for multiple versions of the N-R 1 vehicle body shell, saving significant time and expense compared to building and testing numerous physical prototypes. Experimental wind-tunnel results closely validated analysis output and enabled engineers to arrive at an aerodynamically optimized design. Using the software, the development team lowered the drag coefficient from 0.33 of the initial vehicle body shell design to less than 0.28 for the current optimized design.



Fluid flow analysis helped engineers to reduce drag coefficients on the prototype N-R 1 body shell.

The CHB engine bears little similarity to traditional internal combustion engines, in which pistons move up and down in a reciprocating linear motion. In contrast, a set of opposing torus-shaped pistons in the CHB oscillate in a rotary motion. Increased efficiency is attained using two compression strokes per combustion chamber to rotate the crank shaft. In addition, a patented kinematic control mechanism and linkage alter the engine's compression ratio on the fly while in operation. Performance is further boosted through the use of engineered composite materials that require no lubrication or liquid coolant to maintain proper operating temperatures. Fewer moving parts, such as wrist pins, valves, water pump and oil pump, lead to a 30 percent reduced part count and an increased engine power-to-weight ratio.

Engineers used ANSYS Mechanical software to determine stress distribution in engineered composite material pistons, which oscillate in a rotary motion.

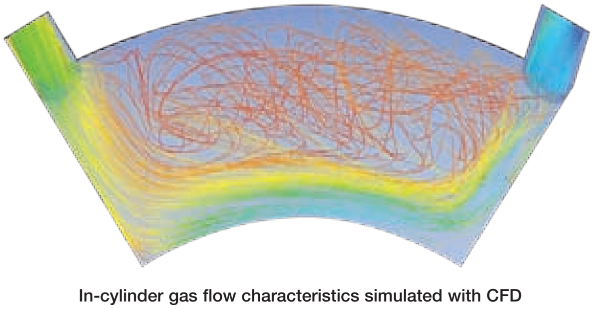
To study the combustion and thermal behavior of the CHB, engineers used predefined defaults to create a moving and deforming mesh (MDM) to set up in-cylinder gas flow characteristics for multiple fluid structure interaction (FSI) analyses. In these studies, mass air flow was determined efficiently using complex ANSYS FLUENT analysis of more than 12 million elements. With this fluid model, engineers could effectively analyze in-cylinder combustion to achieve a homogeneous mixture and optimal burn. This, in turn, yielded the highest-possible efficiency for a given fuel mixture.

ANSYS Mechanical software was also an integral part of the CHB development effort. In one stage of the project, the engineering team used the software to analyze piston stresses while applying realistic loads onto the piston face and incorporating frictional coefficients between the cylinder bore and the piston mantel. In particular, engineers focused on engineered composite material components to determine the feasibility of various designs and to identify imminent structural failure. In these cases, when composite material components are studied in relation to adjacent metal parts, contact elements were useful in modeling touching parts of dissimilar materials. Also, parameterization of simulation models and bidirectional connectivity with CAD software were important to reflect changes in components' dimensions so that sensitivity studies could determine the best design in terms of performance, reliability and material costs. This approach saves considerable time in physical prototype testing and leads to optimal designs that are impractical to explore with mockups.

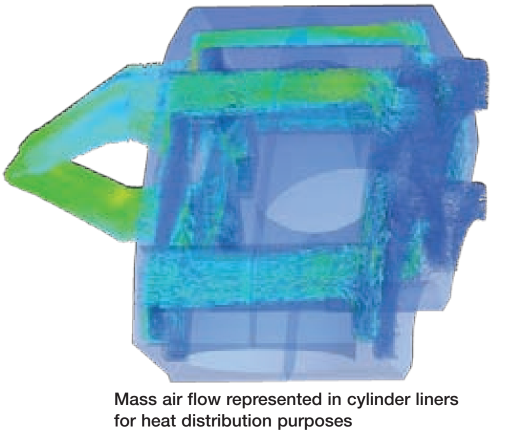
In this analysis, the engineers imported component geometry from the CAD system using the ANSYS DesignModeler tool. This technology was fast, seamless and helpful in tasks such as surface splitting to prepare the geometry for meshing. The simulation model was created using multiple settings such as tetrahedral or hex-dominant meshes made with the ANSYS Workbench meshing application. Boundary conditions (constraints, contacts, joints, loads, etc.) were then defined using ANSYS Mechanical technology.

Following the structural analysis stage, engineers used the engineered composite material component's model generated by ANSYS Workbench for an ANSYS Mechanical thermal analysis. Due to the difference in expansion coefficients, this is very important for applications in which cylinder liners are composed of common metal alloys. The simulation is performed to ensure proper piston–bore gapping during normal operating temperatures, which range from 450 degrees to 1,100 degrees C.

Engineers found the user-friendliness and speed of ANSYS Mechanical to be two of the most important advantages of products from ANSYS. The resulting efficiency in software use allowed the Niama-Reisser engineering department to readily conduct a series of iterative

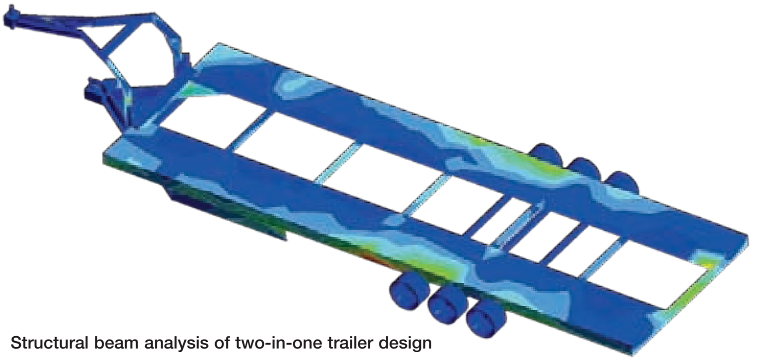


In-cylinder gas flow characteristics simulated with CFD



Mass air flow represented in cylinder liners for heat distribution purposes simulations to refine the design, thus avoiding numerous trial-and-error prototype test cycles. Indeed, prototyping costs — primarily in the development of the CHB engine family — have been reduced 60 percent since the introduction of ANSYS products at the company.

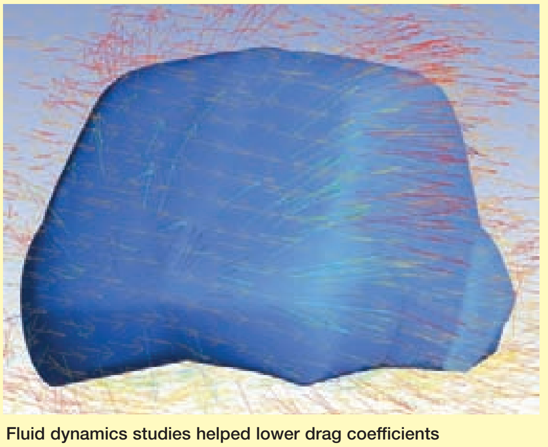
Niama-Reisser has employed ANSYS Mechanical capabilities for a wide range of other projects with significant advantages over the previously used structural analysis software. In structural beam applications, solution times have been typically reduced 70 percent to 100 percent with ANSYS Mechanical, which also provides much faster and more stable problem configurations.


Structural beam analysis of two-in-one trailer design

These advantages were evident in yet another application, an innovative two-in-one trailer design that serves as a gooseneck trailer connected to a truck bed or an attchment to a dead-weight "bumper trailer" hitch. The previous analysis software platform had difficulties in creating the 3-mm fine mesh needed for detailed analysis; the program crashed often because of long compute times and meshing difficulties. Moreover, multiple separate steps had to be performed to set up a cylindrical coordinate system necessary for the analysis. In contrast, ANSYS Mechanical software provided the clean, straightforward user interface required to easily set up such problems with the click of a mouse. ■

Selecting the Right Software for the Job

Niama-Reisser ran substantial benchmarking to compare computational fluid dynamics (CFD) software offerings and selected the ANSYS FLUENT program for work such as determining drag coefficients for vehicle aerodynamics and analyzing fluid flow inside engine cylinders for piston cooling studies.


Fluid dynamics studies helped lower drag coefficients for vehicle body shell.

Outstanding customer support from ANSYS technical support staff in these complex applications and subsequent exceptional fluid flow simulation results gave engineers high confidence in products from ANSYS. The successes with fluid flow applications prompted Niama-Reisser to switch from a CAD-based finite element package to ANSYS Mechanical software for structural and thermal analysis. The pro-ANSYS decision was based on several compelling reasons, including:

- Substantially decreased processing times with ANSYS software, typically beyond 50 percent
- Better meshing capabilities regarding improved element transitioning and higher mesh densities in detailed regions of the model
- Ability to handle large assemblies efficiently with high-performance computing
- Broad base of integrated solutions in the ANSYS product portfolio
- Straightforward interface and ease of use in applying features for complex problems