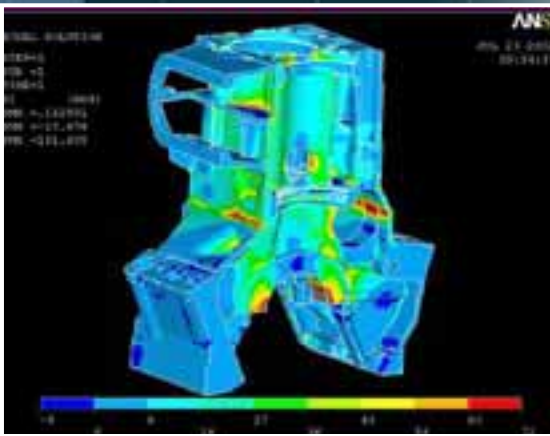


Capabilities in Engine Design

Combining Technology with Experience
From Concept to Hardware



SOUTHWEST RESEARCH INSTITUTE®



Introduction

SwRI has built an experienced team of more than 40 engineers and technical specialists to assist customers in engine design and development through meeting new product requirements, improving exhaust emissions, increasing fuel economy, and improving power output. Approximately 600 of their combined 1,000 manyears of technical experience were acquired during the team's previous employment at major engine original equipment manufacturers (OEMs). This experience base enables our team to understand your needs from your perspective.

This strong, industry-based background, coupled with state-of-the-art tools and the latest in design techniques, enables the team to provide the best balance between practical, experience-based engine development and cutting-edge technologies. Utilizing a product-centered approach to component and system design problem solving, SwRI works closely with customers to design custom programs tailored specifically for individual customer needs.

The SwRI Advantage

Improved Design Process

SwRI has developed techniques to introduce complex computer-aided engineering (CAE) early in the design process so that meaningful results are available early enough to influence tooling design. Traditional design methodology falls short in this regard because complex simulation is reserved for models with final detailed geometry. Because schedules normally require prototype tooling to be designed before final component geometry is available, traditional design methodology does not provide complex analysis results early enough to influence tooling design. At SwRI, expensive tooling always benefits from complex analysis.

Product-Experienced Analysts

A typical discontinuity in engine design programs is that the engineers performing analytical work are not the same engineers with product development exper-

tise. SwRI analysts have backgrounds in product development and manufacturing and understand the requirements and limitations they impose upon real hardware. This experience provides for overall superior designs to those derived from a strictly academic approach. Additionally, our staff maintains involvement in the SwRI Engine Benchmarking Program and has access to the Institute's internal engine database to ensure familiarity with current and past commercial hardware.

Design Tool Philosophy

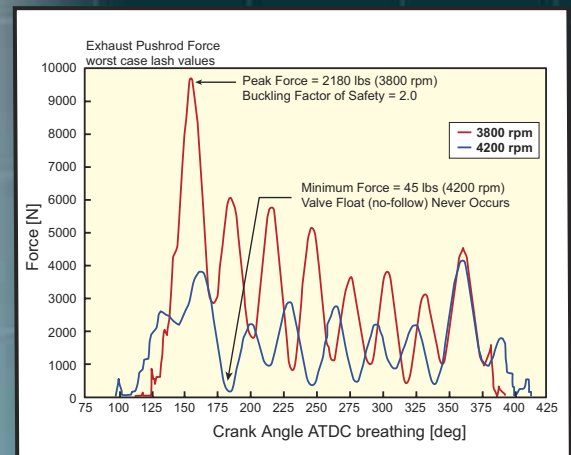
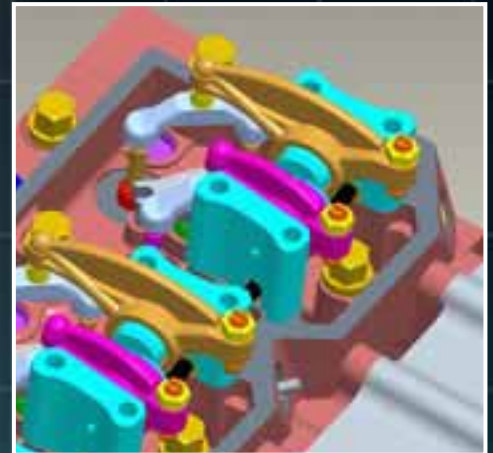
When it comes to engine design at SwRI, software is not the focus. Our emphasis is on the knowledge, skill and experience of the designer/analyst using the software, not the software program used. For this reason, the design team does not develop software for commercial sale or use, and internal code is written only when commercial software is not available. SwRI has well-developed and proven analysis procedures that can be applied with various codes. The Institute maintains a large database of results that serves as the basis for effective design limits.

SwRI Technology Transfer Policy

SwRI was founded to solve our customer's problems through the application of both proven and innovative technologies. Because our customers' competitive strength is a top priority, SwRI retains no intellectual property rights to technologies developed as part of customer-funded operations. At SwRI, we work for you.

Global Presence

The SwRI Engine Design team maintains a global presence through past successful projects with customers worldwide and also regularly teams with satellite offices located in both the United Kingdom and China (www.chinaoffice.swri.org). Additionally, the Institute is currently involved in a successful joint venture in China. In the United States, SwRI operates an office staffed with engineers and support personnel in Ann Arbor, Michigan (www.annarbor.swri.org) in addition to its primary facilities in San Antonio, Texas.

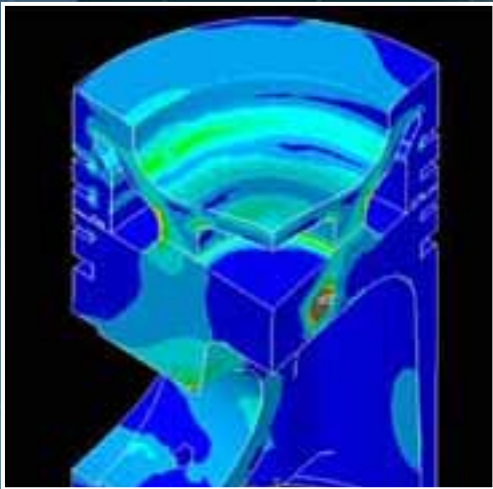
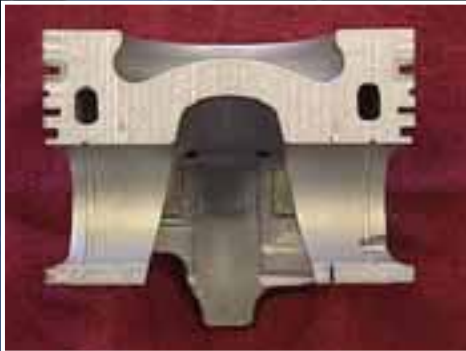




SwRI's Design Capabilities

From the development of an idea to the developmental testing phase, the SwRI team is able to help customers formalize concepts and carry them forward. Because of the industry experience of our SwRI staff and broad engine design familiarity resulting from the Institute's engine database and benchmarking program, Our engineers have the knowledge and skills necessary to carry out engine design, analysis and development activities for all systems and components, including:

- Valve train
- Cylinder head
- Gear/chain drives
- Combustion and engine performance
- Piston and rings
- Cylinder block
- Crankshaft
- Bearings
- Cooling and lubrication systems
- Exhaust and induction systems



Program and Project Planning

No two engine development programs are identical. Determining how to employ the right resources at the right time is critical for a successful project. SwRI team members have been deeply involved in numerous engine design and development programs over the years. This experience has led to the development of techniques for program planning that will optimize the use of available resources and give the project the greatest probability of product success. SwRI can help you evaluate your team's capability to design and develop a successful product and highlight areas of high risk. Because SwRI team members have "lived" in the real product development environment, they understand the issues and are able to help in the program or project planning stages. The goal is a project that is tailored to the customer's objectives, resources and budget – with all the risks identified up front.

Product Problem Solving

A unique benefit of the team's background is experience in solving a variety of specific product problems. When necessary, SwRI design team members with pertinent experience can be assembled for a one-day meeting with customers to address a particular product



issue. During these meetings, critical parameters can be identified, previous solutions can be discussed, and guidance can be provided for the best path forward. Many customers have found this method to be an economical way to quickly identify solutions to design-, material-, and manufacturing-related problems.

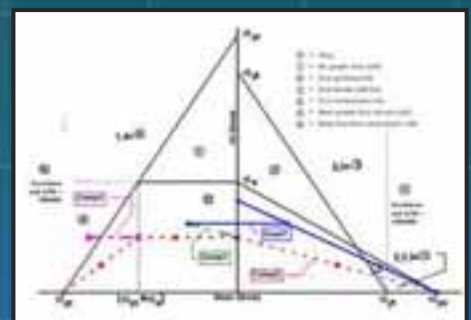
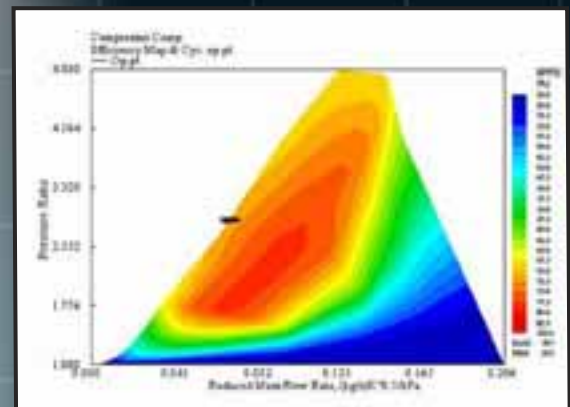
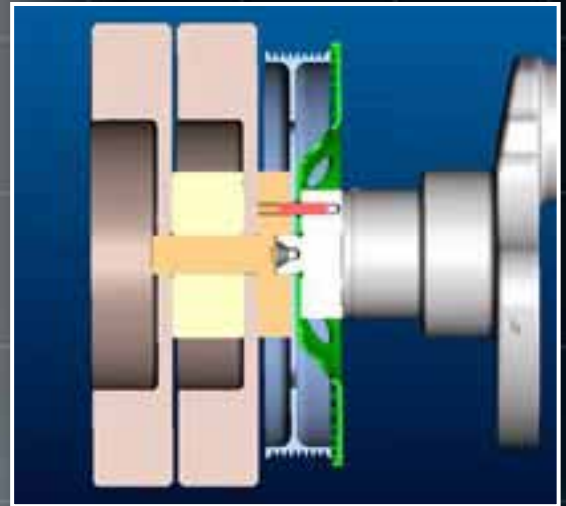
Conceptual/Classical Design

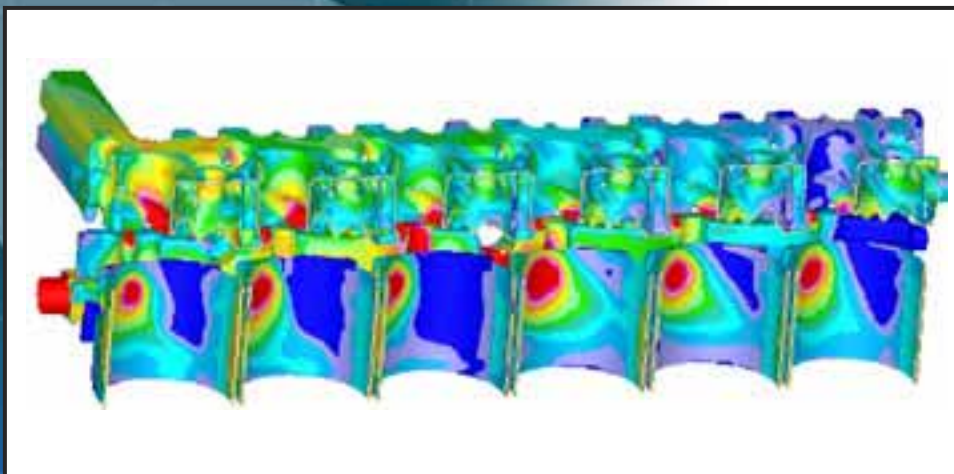
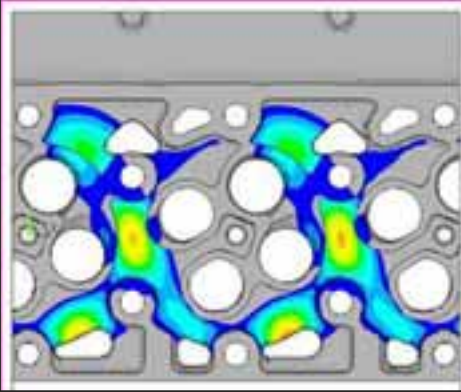
The SwRI engine design team utilizes its familiarity with a broad cross section of engine designs as the foundation for all new design concepts. Although specializing in heavy-duty diesel engines used in a wide variety of applications, team members are experienced with many different engine types, ranging from small gasoline-powered utility engines to large, natural gas-fueled stationary power generation units. In addition to its extensive industry-based experience with a large number of internationally recognized engine design organizations, involvement in the SwRI Engine Benchmarking Program, and access to the SwRI engine database, the team provides the necessary technical depth and breadth to make informed design decisions.

SwRI engine designers use a wide array of classical analysis techniques to quickly ascertain design suitability and provide guidance during engine concept definition. In-house and commercial tools make classical calculations quick, easy, and accurate. Hardware requirements are calculated based on customer needs, and once approved, a detailed design can be presented early in the project evolution. Some of the systems for which preliminary dimensional data is derived using classical analysis are:

- Cranktrain components
- Valvetrain components
- Bearings
- Critical fasteners

During the conceptual design phase and in conjunction with classical analysis, components requiring complex tooling are analyzed using preliminary CAE techniques developed by SwRI. The results are used to guide tooling design, which must normally be completed well before detailed component models are available. The result is better tooling and a reduced occurrence of design modification requirements in the latter design stages.





Advanced Simulation (CAE)

SwRI has a full complement of advanced analysis tools to evaluate and optimize the thermodynamic and mechanical behavior of engine components and systems. These tools include the following:

- Finite element analysis
 - block and cylinder head castings
 - head gasket and block-head-gasket assemblies
 - crank train components
 - valve train components
 - manifolds
 - mounting hardware
- Computational fluid dynamics
 - combustion and in-cylinder flow
 - fuel system
 - cooling and lubrication systems
- Multi-body system dynamics
 - crank train
 - valve train
 - accessory drive
- Cycle simulation
 - manifolds
 - turbochargers
 - valve timing
 - in-cylinder parameters
 - compression ratio
 - bore
 - stroke
 - displacement

Detailed Design

SwRI capabilities in detailed modeling and drafting extend to multiple CAD environments, allowing compatibility with customers' in-house tools. SwRI designers also have configuration management expertise, enabling coordination of design input from multiple sites when required. The hands-on philosophy of the design team extends to its CAD designers, who conduct design verification and modification exercises at foundries and other fabrication facilities to ensure their design intent is accurately captured in production.

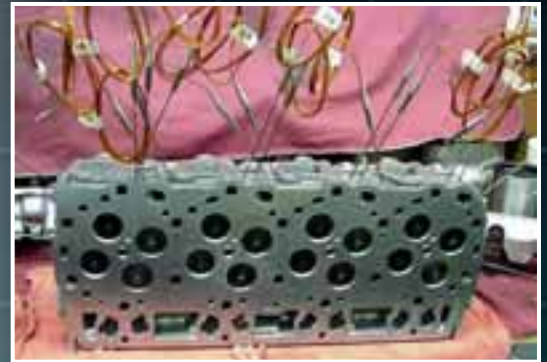
Prototyping

The SwRI Engine Design Team is able to deliver a concept from inception to prototyping to proof of performance. After a design is complete, SwRI can provide rapid prototyping with a combination of in-house and supplier-based capabilities, including stereolithography and selective laser sintering.

Rig Testing

SwRI maintains a wide variety of durability and performance test rigs in support of its engine design activities, including:

- Fatigue test rigs for cylinder blocks, cylinder heads, and connecting rods
- Flowbench with swirl and tumble measurement capabilities
- "Hot shaker" for elevated temperature catalytic converter testing
- Turbocharger testing





Southwest Research Institute is an independent, nonprofit, applied engineering and physical sciences research and development organization using multidisciplinary approaches to problem solving. The Institute occupies more than 1,200 acres and provides nearly two million square feet of laboratories, test facilities, workshops, and offices for more than 3,000 employees who perform contract work for industry and government customers.

We welcome your inquiries.

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