SIEMENS
Ingenuity for life

Marine

Cardinal Engineering

Custom programs automate finite element modeling and postprocessing

Product

Femap with NX Nastran

Business challenges

Produce high-fidelity, low-cost modeling and analysis results for many unique foundation designs

Keys to success

Develop innovative methodology to meet aggressive schedule

Automate and streamline FEA modeling and postprocessing

Use Femap application programming interface (API) to develop custom programs

Results

Reduced modeling and analysis time by 80 percent

Enabled direct import of geometry and technical data

Realized cost savings for the customer

Won additional work from the customer

Cardinal Engineering builds automated analysis tools using Femap application programming interface

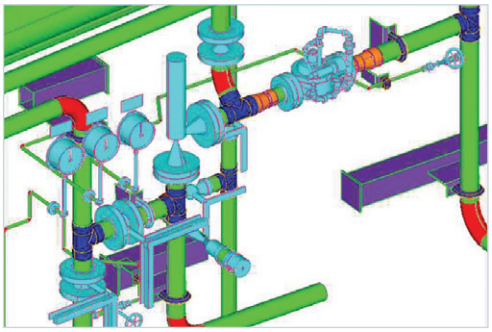
Landing a challenging engineering task

Cardinal Engineering (Cardinal) is a small engineering services firm providing services to government and commercial clients with a primary focus on the marine sector. The company's expertise includes naval ship design and analysis, naval power and energy systems, and ocean energy technology development.

Since the company's inception, Cardinal has used Femap™ with NX™ Nastran® software from product lifecycle management (PLM) specialist Siemens PLM Software as its primary solution for finite element analysis. Cardinal's engineers are intimately familiar with the capabilities of the software. Cardinal relies on Siemens PLM Software solution partner Structural Design & Analysis, for technical support of Femap and NX Nastran.

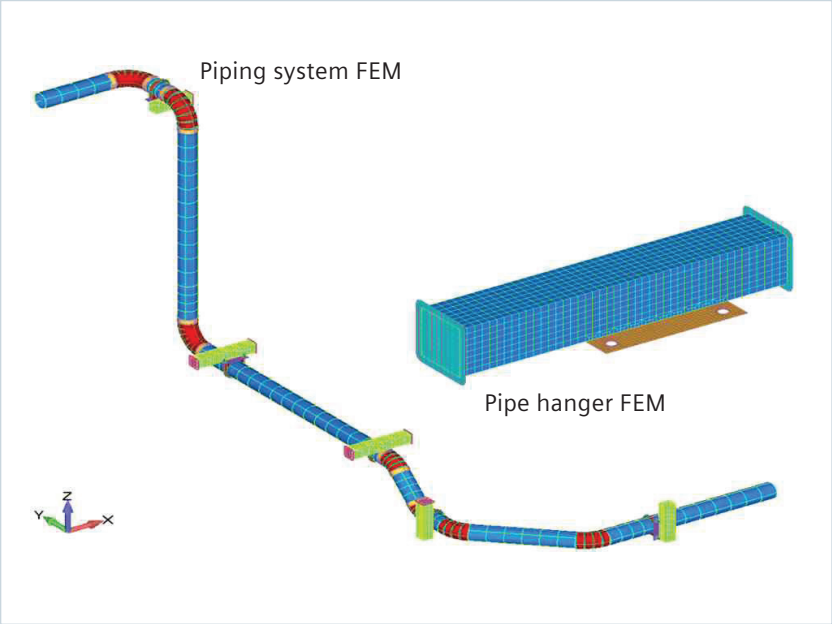
Cardinal's primary business challenge was to establish a foothold in the highly competitive marine industry with limited work. The company relies on the experience, innovation, work ethic, and established customer base of its engineers, and does not seek to win projects based on cost, and increasingly wins on reputation.

As a small business with experienced engineers but little name recognition, it



was imperative that Cardinal land a challenging analysis task to prove its capabilities to a major navy shipyard. Success would help secure the company's reputation as an innovative engineering firm capable of performing complex analyses on naval combatants. It would also enable the company to compete with larger, established analysis firms for future work.

"To win this work, we needed to convince the customer that we could analyze, assess, and document over 1,000 unique shipboard pipe hanger foundation designs in a very short time frame – six months," says David Batol, senior engineer at Cardinal. The pipe hanger foundations include linear pipe segments, bends, elbow reducers, hangers, clamps, U-bolts and other piping components. To complete the project, Cardinal engineers needed to review the technical data for the pipe hangers and piping systems, develop finite element models, conduct analyses, identify failed foundations, redesign the hangers as needed and submit formal reports documenting their analysis work.



Finite element model of piping and hangers (cross-sections shown for clarity of beam elements).

"An additional benefit of our methodology was the identification of issues with the information provided by the shipyard, such as faulty CAD files, that helped the customer improve their quality control processes."

Chris Mairs
Principal Engineer
Cardinal Engineering

Cardinal's engineers were accustomed to developing finite element models manually using the meshing tools of Femap, or by importing and manipulating computer-aided design (CAD) geometry to build the mesh. For postprocessing the analysis results, the company's engineers typically reviewed analysis results manually using Femap, and in some cases performed closed-form calculations using the analysis results to verify that they met the acceptance criteria.

The primary technical challenge was the sheer scope of analyses required for the project, with limited manpower against an aggressive schedule. Prior to contracting this work, the shipyard was analyzing approximately 50 foundations per year per engineer, utilizing their own engineers and conventional processes. Employing the typical finite element modeling build and analysis process was not an option.

Innovating a winning methodology

The key to Cardinal's success on this project was an innovative methodology it developed for meeting the aggressive schedule demands of the customer. "Other competitors on the project focused on statistical approaches in their proposals, but we recognized the power of the Femap API and had personnel with the expert programming skills needed to maximize it," says Batol.

Cardinal's strategy was to automate and streamline the finite element modeling, analysis and postprocessing to actually perform a full, in-depth analysis on each hanger foundation. With this approach, the company could use relatively little manpower to complete more than 1,000 independent analyses.

"To win this work, we needed to convince the customer that we could analyze, assess, and document over 1,000 unique shipboard pipe hanger foundation designs in a very short time frame – six months."

David Batol
Senior Engineer
Cardinal Engineering

"Other competitors on the project focused on statistical approaches in their proposals, but we recognized the power of the Femap API and had personnel with the expert programming skills needed to maximize it."

David Batol
Senior Engineer
Cardinal Engineering

Leveraging the capabilities of Femap with custom programs

Using the Femap API coupled with the open-source Python programming language, Cardinal's engineers scripted and compiled a series of programs to automate many modeling, analysis and postprocessing steps that were typically conducted manually. The Femap API enables programmers to access Femap commands for constructing models and postprocessing results and also to create custom tools for specific tasks. Femap includes extensive documentation of the API, along with examples and built-in custom tools that assist in learning how to create programs.

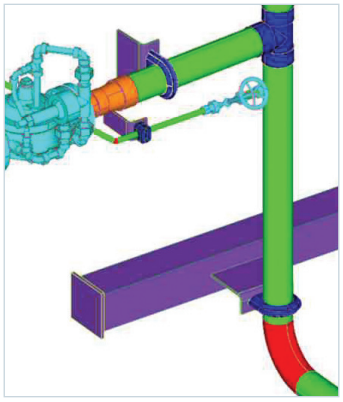
The shipyard provided the CAD geometry of the piping system in the form of Standard ACIS Text (SAT) files as the primary input for the analysis project. Cardinal's engineers created custom programs that automated construction of finite element models based on the imported CAD geometry.

Upon selection of the solid models of piping components, the custom programs automatically create line geometry between the center points of pipe ends, then mesh the lines to create beam elements and specify orientation vectors.

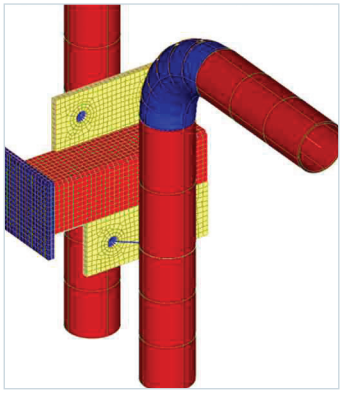
Next, the program creates or assigns Femap properties for pipe segments, including fill condition, material, and inner and outer diameters (determined by processing the CAD geometry). The program then continues processing the next solid model in the selection set.

The Cardinal team created programs for all the components of the piping run and hanger foundation, including linear pipe segments, bends and elbows, tees, reducers, pipe components, square tubes, U-bolts and clamps. The programs for each component type include specific steps that automatically create appropriate finite element meshes, midsurfaces and nodal masses based on the geometry. When needed, the programs also access component technical data from Excel® spreadsheet software.

For postprocessing tasks, Cardinal engineers developed additional programs that determine maximum stresses from analysis output sets; perform plate pull-through and tear-out stress calculations; and calculate bolt stresses. For these calculations, the programs also output the resulting data to Excel spreadsheets. Another program creates images of stress plots from output sets. All of the programs are accessible through a custom toolbar in the Femap user interface.



CAD geometry model of a pipe linear segment, bend/elbow and U-bolt connection.



Typical compartment arrangement.

Solutions/Services

Femap
www.siemens.com/plm/femap

Customer's primary business

Cardinal Engineering provides engineering expertise to government and industry customers, developing systems that operate in the world's oceans. Working with the United States Navy and other federal agencies, the company helps achieve critical national missions related to the security and well-being of its homeland.
www.cardinalengineering-llc.com

Customer location

Annapolis
Maryland

Partner

Structural Design & Analysis (SDA)
www.structures.aero

Using the Femap API coupled with the open-source Python programming language, Cardinal's engineers scripted and compiled a series of programs to automate many modeling, analysis and postprocessing steps that were typically conducted manually.

"The application of custom tools enabled us to reduce the time for developing finite element models and postprocessing analysis results by a factor of at least ten," says Chris Mairs, principal engineer at Cardinal. The company used three full-time engineers to model, analyze and document more than 1,000 pipe hanger foundation designs in just six months. "An additional benefit of our methodology was the identification of issues with the information provided by the shipyard, such as faulty CAD files, that helped the customer improve their quality control processes," Mairs says.

With the success of this project, Cardinal gained confidence in the experience of its engineers as well as in the Femap API and custom programming. The company is continuously seeking business opportunities in large-scale, repetitive analysis projects that would lend themselves to a similar approach.

"The application of custom tools enabled us to reduce the time for developing finite element models and postprocessing analysis results by a factor of at least ten."

Chris Mairs
Principal Engineer
Cardinal Engineering

Siemens PLM Software

Americas +1 314 264 8499
Europe +44 (0) 1276 413200
Asia-Pacific +852 2230 3308

www.siemens.com/plm

53279-A9 12/16 H