P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

AAM Sees Dramatic Productivity Gains, Cost Savings from Automating NVH Analysis Process with New Comet NVH Driveline SimApp

By Bruce Jenkins, Principal Analyst, Ora Research LLC

American Axle & Manufacturing, Inc. (AAM) is a leading global Tier-One automotive supplier of driveline and drivetrain systems and related components for light trucks, SUVs, passenger cars, crossover vehicles and commercial vehicles. The company has a long history of successfully using FEA to master the many NVH (noise, vibration and harshness) challenges in any driveline engineering project – gear whine, gear rattle, shudder/moan/chatter, clunk, propshaft instability and others. Nevertheless, its traditional simulation methods had limitations:

- Constraints on engineering productivity and resources made it a challenge to compete on cost-competitiveness without sacrificing innovation.
- Manual processes and dependence on CAE experts resulted in lengthy cycles of two to three hours per analysis iteration.
- Errors in analysis were a risk due to manual work, impacting reliability and cost.

To attack these limitations, AAM decided to implement Comet Solutions, Inc.'s NVH Driveline SimApp – a new software application that lets users set up and utilize libraries of parameterized 3D, 2D, 1D and 0D (mixed-fidelity) representations of propshafts, axles and related components to fully automate the configuration and NVH analysis of driveline systems. The result is a single environment for driveline NVH analysis that allows quick and easy evaluation of any geometry, without the manual effort of traditional approaches.

Glen Steyer, AAM's Executive Director of Product Engineering, reports major benefits from the new tool:

- Average 75% time reduction for each analysis iteration.
- Approximately $130,000 in annual cost savings at a single engineering site.
- Improved quality through globally enforced standards and practices which remove human error.
- Ability to run many more NVH analysis iterations, leading to more design decisions, earlier.
- Ability to redeploy resources as less experienced engineers are now able to *safely* run simulations.

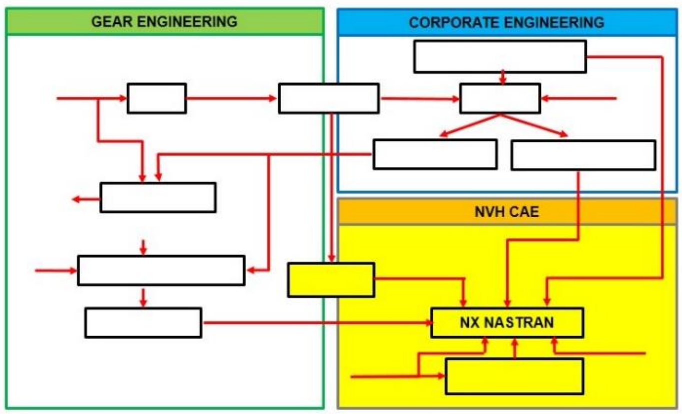
AAM was so impressed that it now plans to deploy the NVH Driveline SimApp at its China and India engineering sites, then implement additional Comet Driveline SimApps to cover its entire CAE process including gear systems analysis and strength/stiffness calculations. Beyond the time reduction in analysis iterations, Steyer sees great strategic benefit in using Comet SimApps to make simulation experts' knowledge more broadly available across engineering teams – as well as to help "forward-deploy" simulation to the earliest stages of product development, where it can have deep impact on innovation at the product architecture level.

Ora RESEARCH
P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

Defining the Need

What led AAM to engage with Comet? "Over the years," Steyer explains, "especially recently, we have put more and more focus on how to standardize and capture our processes, and automate them – both for improving the quality of analysis by eliminating input errors, and for forward-deploying the simulation technologies, especially to our regional offices which interface with our customers globally. For all these goals, Comet looked like a worthwhile capability to investigate."

The schematic below, which illustrates the complexity of AAM's analysis data/workflows, was used to analyze the potential benefits of using Comet software. The decision was made to focus initially on the bottom right portion of the workflow – performing modal and vibration response calculations using Nastran.



AAM's CAE work processes, like those of most manufacturers, required a great deal of manual effort:

- The data needed to create Nastran models originates from various sources, in a variety of formats. This data was gathered manually and assembled into a Nastran deck. If a CAD model for the shafts did not yet exist, the user manually entered "trial" finite element data based on geometry description – all a time-consuming and potentially error-prone process.
- The propshaft, hypoid gear set and bearing models are the portions of the design that most need to be modified parametrically, to evaluate design options. These are modeled using 1D beams, 0D point masses, 0D bushings, and connectors such as rigid spiders. Adding this data to the Nastran model was done manually and could take considerable time. And there was no feedback to ensure correctness.
- Engineers also need the ability to choose an initial shaft design from a library of possible designs. Traditionally this was done in a fairly *ad hoc* way, using Nastran model files to store various versions of a shaft. Then the engineer had to manually connect this portion of the finite element model into the rest of the file.
- The differential housing is usually modeled using 3D and is available as CAD data that is directly meshed.
- During a driveline program, AAM engineers would like to perform analyses of the driveline over a wide range of parameter changes, to evaluate performance of various options rapidly. Ultimately, DOE (design of experiments) and optimization studies also need to be performed. To make this feasible, the Nastran models need to be automatically generated without manual user intervention.

Ora RESEARCH
P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

Working with AAM experts to understand their requirements, Comet used its Abstract Engineering Model (AEM) and Intelligent Template technologies to develop this NVH Driveline SimApp to make it easy to set up and utilize libraries of parameterized 1D/0D representations of propshafts and axles. The goal was to fully automate the configuration and NVH analysis of complete driveline systems with at least 30% productivity improvement. Further, AAM wanted to fully automate parameter studies, DOE and optimization runs, using both geometric and non-geometric design variables to rapidly explore the design space.

Benefits Realized

AAM is impressed with how well the new software meets these goals. Thanks to the NVH Driveline SimApp – now a ready-to-deploy driveline simulation solution from Comet that works with the industry's leading structural FEA solvers – AAM reports major advances in its NVH analysis processes:

- Ability for engineers to rapidly configure a driveline design, choosing from libraries of housings, propshafts and axles.
- Full automation of model preparation for NVH calculations.
- Standardization of nomenclature, finite element model generation and results extraction across the global organization.
- Automation of results extraction and report generation.
- Average time reduction of 75% in model preparation, results extraction and report generation for each analysis iteration and loading scenario.

The benefits are in three major functional areas:

- **Modeling Systems and Subsystems** Many aspects of a driveline are efficiently defined using 0D/1D/rigid entities such as beams, bushings, point masses, rigids, etc. With traditional methods, adding these to CAE models was often a highly manual process. The new SimApp lets users define these systems abstractly and parametrically, then reuse them in combination with other higher-fidelity representations in 2D and 3D.
- **Assembling a System Model** To help engineers perform analyses of a driveline design over a wide range of parameter changes for rapid evaluation of design alternatives, and to carry out DOE and optimization studies for rapid design space exploration, the Nastran models need to be automatically generated without manual user intervention. To this end, the new SimApp makes it easy to:
    - Import an existing mesh.
    - Import CAD for other portions of model; these CAD subsystems are then meshed in the SimApp.
    - Define 0D/1D subsystems in the SimApp, such as beams, bushings, point masses, rigids, etc., which can be defined parametrically, then linked up with the rest of the model as it morphs.
    - Define connections between the subsystems.
    - Mesh the 0D/1D subsystems in the SimApp.

  The final mesh is assembled automatically from all these sources, then sent out for analysis.
- **Maintaining and Reusing Systems** Subsystems (for example, a propshaft or universal joint) can be defined parametrically, then saved and reused. A system can be assembled from multiple subsystems. And subsystems can be swapped in and out, including externally defined meshes (such as for the differential housing).

OraRESEARCH
P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

Payback and ROI

AAM's traditional NVH analysis methods suffered from schedule-gating constraints – manual work process for each geometry and load/test case, need for experts in meshing and Nastran NVH calculations, manual results extraction and report generation. With the new NVH Driveline SimApp, these processes:

- Are fully automated – the user simply configures the driveline and runs.
- Use a single, consistent systems repository for shafts and axles.
- Use standardized and *enforced* nomenclature and best practices, across the global organization.
- Can be made accessible remotely via the Web.
- Do not need experts at the point of use.
- Provide fully automated results extraction and report generation.

Average 75% Time Savings per Analysis Iteration "We're still early in deployment," Steyer notes. "The evaluation we did was focused on design robustness, analysis and analytical design of experiments. In that situation we're doing a nominal model, identifying different parameters, adjusting those over a range of values, and evaluating the effect on response. Through that evaluation, we determined that the man-hours required to do the simulation was reduced by about 75% – that's the primary benefit we've seen so far."

Capturing and Globally Deploying Expert Knowledge Going forward, AAM is exploring "the benefits of having a simulation expert define the template for a given analysis, thus enabling a design engineer to execute that simulation in an automatic fashion," Steyer says – a key enabler in helping AAM deploy its central engineering expertise to regional offices around the world. "As a company we're highly focused on globalization," Steyer explains, "and we're deploying appropriate capabilities in our regional offices – deploy the analysis tools locally in each region, meet with their customers, come up with the right solutions for that regional market. In doing so, obviously we want to leverage the years of knowledge from the analysis experts at our world headquarters. This SimApp lets us take those decades' worth of knowledge and expertise, put it into the simulation tool, and forward-deploy that to our engineers around the world."

ROI Summary

- **Simulation automation** across the manufacturer's family of products:
    - Reusable library of parametrically defined 1D/0D representations of propshafts, axles and any other user-defined subsystems.
    - *Significant* time savings and reduction of manual errors.
    - Ability for lower-level and less experienced engineers to run these calculations.
- Ability to automate **DOE and optimization** calculations across all levels of fidelity, using any of the analysis tools, *including geometric design parameters.*
- Single, consistent **systems repository:**
    - Consistency of systems data across all fidelities, tools and physics, including CAD (2D/3D) + 1D/0D abstractions + connectors.
    - Single view of all product analysis data which is shared across the tools.
- Auto-generated **analysis reports immediately shareable across globally distributed design teams**, providing a single, consistent view of all model and results data across the tools.

Ora RESEARCH
P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

Implementation: Cultural and Organizational Factors

Were there cultural and organizational factors to consider in adopting the new technology and work processes? "It's exactly those cultural barriers," Steyer observes, "that get in the way for a lot of organizations. Like many companies, we have highly knowledgeable experts in individual silos, and they take great pride in what they do and the quality of their work – rightly so. Staff like that have traditionally been rewarded or compensated for the degree to which each one gives his or her individual knowledge and capability to the organization – what each one personally contributes."

What's different with the new SimApp-enabled work process? "With this approach," Steyer says, "you need to tell those experts that they are going to define these templates, in order to simplify what *others* can do with the analysis tools. So that will raise reservations about the ways the tools could conceivably be misused. And there is some validity to those concerns." How to address this? "You need to implement this capability with the SimApp to capture and forward-deploy this expertise, but at the same time have processes in place for experts to monitor how the tool is being used – for keeping the experts involved to address their concern that 'somebody's going to take my baby and misuse it in some way.'"

Enabling Systems Thinking Across the Project Team

Beyond the dramatic cycle-time reduction in analysis iterations, Steyer sees great strategic benefit in the Comet SimApps' power to help "forward-deploy" simulation to the earliest stages of product development – and, in so doing, empower discipline experts to look beyond their own silos and work more collaboratively as a team, by gaining a system-level understanding of the project and their role in it.

"We have a lot of experts focused on simulation technology in specific areas of application – gear design, NVH, durability, etc. – and each one is very effective in his or her area," Steyer explains. "But where they have less appreciation is the need to spend less time playing around with the tools tweaking a specific analysis, and instead find ways to put that information out there so that the broader engineering staff can spend more time innovating and creating. Traditional analysis processes spend too much time down in the mechanics of their specific disciplines, rather than innovating and creating at the product level."

A key capability of Comet's new SimApp, he believes, is that "by using a tool like this and forward-deploying it, you can move much more deeply into innovating product architectural dynamics up front in the design process." In the automotive industry, for example, "it's amazing the high level of analytical results and refinement that the customer demands at the up-front contract award stage. Because of that, suppliers have to set designs in concrete way earlier in the process – that forces us to freeze in extra manufacturing costs and other mistakes that can't be backed out of the design later. So starting the design at a system level and doing high-level design studies early lets you get the architecture right. Then later you deep-dive in and do detailed optimization and refinement. To find that system-level architectural definition early on is very important. And when you do that, you're dealing with a broader range of application engineers, so they need these multi-functional models available and offered up to them."

Does AAM's experience with Comet's SimApp show promise for achieving this goal? Absolutely, Steyer says. "After the initial Comet pilot, I pulled together three different teams whose analyses go back and forth and support one another – gear engineering, our NVH group, and our CAE group focused on durability and bearing simulation. I got a

Ora RESEARCH
P.O. Box 61334
Raleigh, NC 27661 USA
tel (+1) 617 875 9598
www.oraresearch.com

kick out of the reaction of almost everyone in those departments, when each one looked at the work done by the other groups and said, 'That's more detailed than I imagined!' The reactions back and forth – 'If you have that information at that point, I can use it over here!' – made it an eye-opening experience when all those disciplines finally had this tool that let them come together."

About AAM

American Axle & Manufacturing, Inc. (AAM) is a leading global Tier-One automotive supplier of driveline and drivetrain systems and related components for light trucks, SUVs, passenger cars, crossover vehicles and commercial vehicles with a regionally cost competitive and operationally flexible global manufacturing, engineering and sourcing footprint. Through highly engineered, advanced technology products, processes and systems and industry-leading operating performance, the AAM team provides a competitive advantage to its customers. www.aam.com

About Ora Research Ora Research's focus is the business and technology of twenty-first-century engineering practice. Our mission is to identify best practices for creating highly engineered manufactured products and high-performance built assets using the latest digital technologies. We seek to identify technologies and attendant work processes that are yielding high return for initial adopters, and are on the cusp of first-wave mainstream acceptance.

We aim to inform and guide professionals with fresh information about these technologies and their successful adoption and application. For engineering, manufacturing and construction organizations and capital asset owner/operators, we offer reports, consulting services and white papers to aid in selecting and deploying new technologies. For technology providers, we qualify and quantify new market opportunities and validate demand drivers. Our goal is to foster insight and action to strengthen the industries we serve. www.oraresearch.com