

Cummins Helps Ensure Generator Set Reliability with nCode GlyphWorks Test Data Analysis Software

Solution requirements:

- Provide the answers to critical questions such as how long a particular component or subassembly will last under a specified set of conditions.
- Eliminate internal development costs of maintaining in-house analysis software.

Cummins Power Generation

Cummins Power Generation is a world leader in the design and manufacture of diesel engine generator sets, spark-ignited natural gas and propane engine generators and lean-burn gas engine generators. All of these products must withstand continual loading in operation and transport while delivering complete reliability to a wide range of critical applications. Cummins engineers utilize static testing, load frame testing, shaker table testing, road testing, etc. to understand fatigue requirements. nCode GlyphWorks test data analysis software plays a critical role by providing the analysis tools needed to make design decisions from large volumes of measured data. "GlyphWorks gives us a wide range of tools that enable us to extrapolate from testing to the real world to ensure that our products can withstand the actual operating conditions in the field," said Gunjan Maheshwari, Senior Mechanical Engineer: Experimental Mechanics for Cummins Power Generation.

Importance of physical testing

Ensuring that it will provide its promised life without failure is important for any product. But fatigue life is particularly critical in the power generation industry where hospitals, telecommunications firms, data centers, emergency services, military units and others rely upon generator sets to carry out their mission in the absence of grid power. Physical testing has played a critical role in the product development process at Cummins Power Generation ever since the company began making generator sets. "Testing generator sets involves huge volumes of data," Maheshwari said. "The challenge is processing that data to provide the answers to critical questions such as how long a particular component or subassembly will last under a specified set of conditions."

In the past, the company wrote data analysis routines in a proprietary development environment. The advantage of this approach is that the software could be customized to address the company's individual requirements. On the other hand, even though the company devoted considerable scarce resources to software development time, it could not duplicate the functionality of



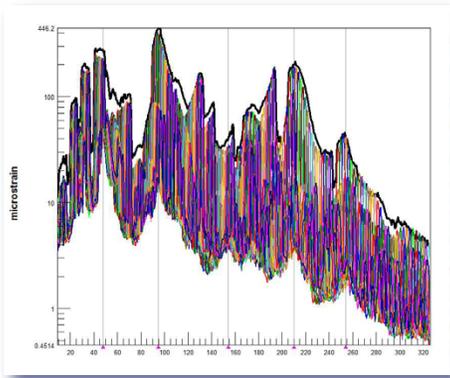
Generator set chassis testing

leading edge test data analysis software. A few years ago, Cummins Power Generation evaluated all of the leading test data analysis software with the idea of eliminating internal development costs while taking advantage of the much greater capabilities that can be provided by a company whose development costs are spread across sales to many customers.

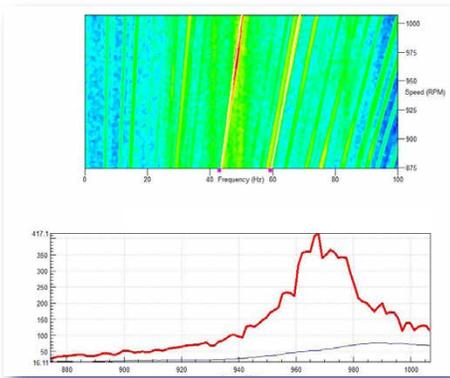
Cummins Power Generation selected GlyphWorks engineering test data analysis software because of its wide range of data processing capabilities including specialized options such as fatigue analysis, accelerated testing, and frequency domain tools. GlyphWorks also integrates with DesignLife to enable test and CAE fatigue in one environment. The software provides a wide range of functions for time, frequency, and statistical analysis, plus synchronized global positioning system (GPS) and video displays. GlyphWorks provides a graphical, process-oriented environment that enables users to create an analysis workflow by dragging and dropping analysis building blocks.



Over the road/field testing



Spectrum analysis for dynamic characteristics



Waterfall analysis for rotating machinery analysis

Ensuring life of radiator fans

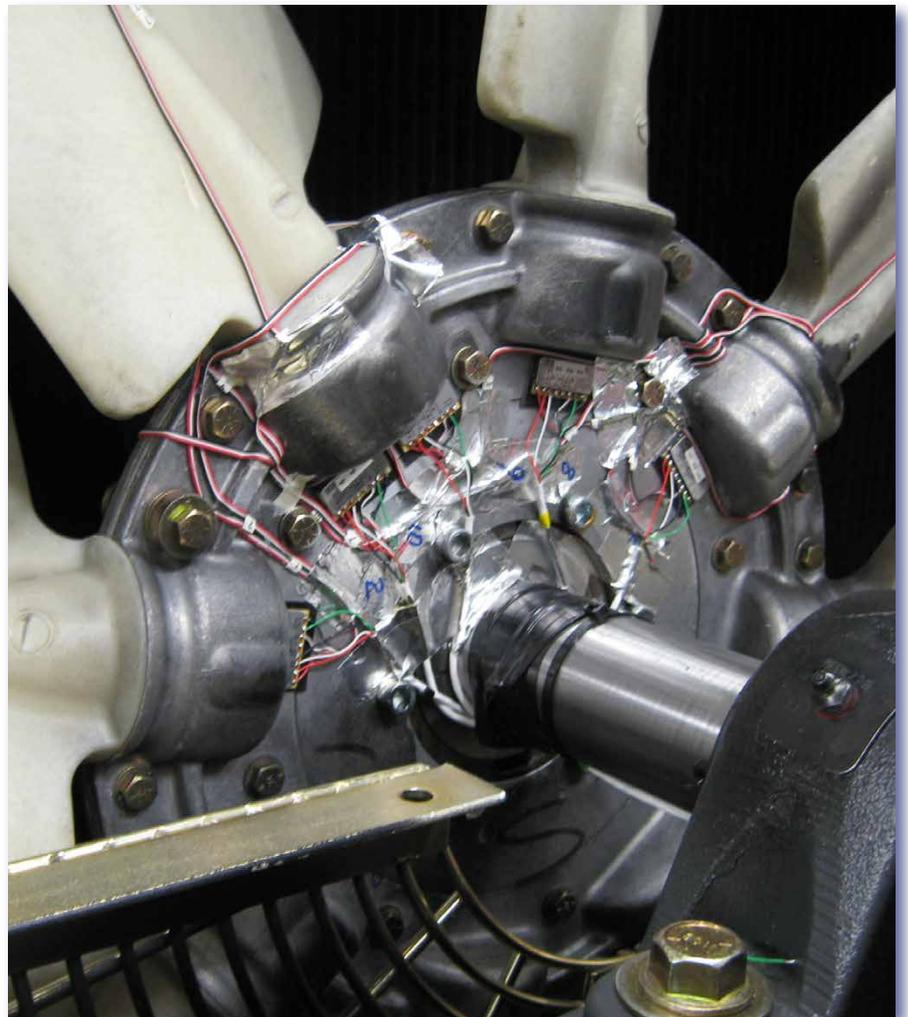
The implementation of this software has helped Cummins Power Generation engineers increase their ability to process test data, resulting in faster and better decisions. As an example, radiator fans are one of the many components whose fatigue life must be carefully assessed. Before testing gets underway, finite element analysis (FEA) is normally used to identify high stress locations. These areas are instrumented with strain gauges. The fan is then spun at its rated speed as well as through startup and shutdown cycles while a slip ring is used to connect the strain gauges to a SoMat eDAQ data acquisition system. A single fan typically generates about 4 gigabytes of acceleration, strain and temperature data, as well as speed and air pressure data.

Cummins Power Generation engineers typically start by using the GlyphWorks drift detection tool to make sure that strains are not drifting due to glue weakening or other causes. The GlyphWorks

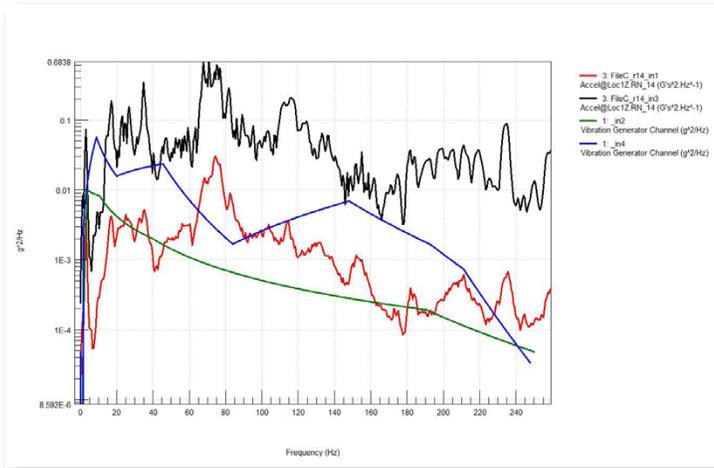
crest factor tool is used to clean up large spikes in the data and the Butterworth filter is used to clean up smaller spikes. Next they might produce a frequency spectrum view of their data to look for resonances and check the noise floor for signal to noise ratio. Once the data integrity is verified, dynamic strain data is used to access the dynamics of structure using frequency spectrums and waterfall analysis with the order tracking method of rotating machinery. The data is further used for fatigue analysis using strain life and/or stress life glyphs which gives an indication of the fatigue life of radiator cooling fans in the application.

In addressing a resonance issue, one option is to change the fan speed to move it away from a resonant frequency. The GlyphWorks order filtering tool is sometimes

used to determine how much of a speed change is needed and to determine which excitation orders could be changed/alterd to avoid this resonance excitation. Another option is to make a design change, such as increasing the thickness of the hub to make it stiffer with an idea that this would change the natural frequency of the fan and could avoid potential resonance issues in applications. If the fatigue life does not meet requirements, then engineers evaluate various methods of making improvements. "We have used these methods to resolve numerous fatigue problems during the design stage," Maheshwari said. "Extensive testing during the design stage helps identify issues and come up with solutions to ensure that our products deliver the reliability that our customers have come to expect."



Fan operating strain measurement



Accelerated Life Testing Test Profile Generation



Accelerated Life Testing in Lab

Producing load histories for shaker tables

Cummins Power Generation engineers also use GlyphWorks to create accelerated life profiles that are used to produce load histories for shaker tables that simulate the effect of transporting generator sets and also generator sets that are used in mobile applications. Engineers install instruments such as accelerometers and strain gauges on the generator sets and vehicles used to transport them. They also capture GPS data and record live video during road testing using portable data acquisition systems like SoMat eDAQ.

Engineers import the data into GlyphWorks and use the amplitude distribution tool to look at the load pattern, for example, to determine if it is random or Gaussian. Various running statistics such as maximum, minimum, mean, root mean square and standard deviation are used to evaluate the data. At the same time, engineers view the data linked with the GPS so they know exactly where the vehicle was traveling – on dirt roads, gravel roads, washboards, etc. – when specific events occurred. The media display tool is used to show live video keyed to the data so that engineers can see the precise conditions that caused each spike.

The next step is to condense the data so its effects can be duplicated on the shaker table in a fraction of the time required to perform the road tests. Cummins Power Generation engineers use the GlyphWorks extreme response and shock response tools to generate a profile that will create the same fatigue loads that the generator set experienced in the field. Then

they put the generator set on the shaker table, run that profile and look for failures. Strain gauges are attached to individual components and the data generated by these devices is input to the strain life tool to predict fatigue life. "Glyphworks has helped us to reduce the testing time considerably yet accurately capture fatigue damage component will experience in application," said Maheshwari.

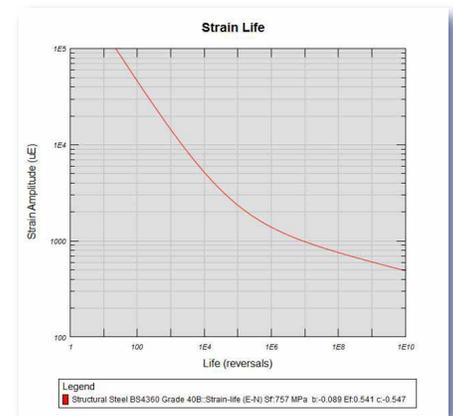
Generator set chassis testing

Cummins Power Generation engineers also perform strain gauge testing of the skids that the generator sets are mounted on. They locate strain gauges at high stress locations based on FEA results and then use GlyphWorks to convert the results to the frequency domain to understand the dynamic behavior of the skid. Strain data is then used in evaluating the fatigue life of the skids or bed frames using strain life/stress life glyphs.



Strain gauges on bed frame

They use GlyphWorks curve-fitting tools to determine the stiffness of the spring/rubber vibration mounts. Similar tools are used in evaluating bolted joints – like evaluating the nut factor. This information is used in turn in simulations to diagnose design issues and optimize the product design.



Cumulative strain life fatigue analysis

"Physical testing is the gold standard to ensure that our products deliver the reliability required for our power generation equipment," Maheshwari concluded. "GlyphWorks helps us deliver on our promises to our customers by providing all of the tools we need to manage and process test data under a single interface. Of particular value is the technology to predict fatigue life from measured data. These tools help us identify and solve potential problems before our products are shipped."

About Cummins Power Generation

Cummins Power Generation designs and builds engine generator sets in the 7 kW to 2.7 MW range, spark-ignited natural gas/propane engine generators in the 7 kW to 150 kW range and lean-burn gas engine generators in the 315 kW to 2 MW range. Cummins Power Generation automatic transfer switches feature microprocessor-based control technology to withstand thousands of switching cycles. The company also provides warranty, planned maintenance, and emergency service including back-up power rental through its network of distributors. Cummins Power Generation is part of Cummins Inc., which has annual sales of more than \$18 billion.



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About us

nCode products are provided by HBM, a world-wide technology and market leader, offering products and services across the entire measurement spectrum, from virtual to physical. Since 1982, nCode is the leading brand for durability and data analysis solutions. Its technologies help customers understand product performance, accelerate product development and improve design. The power and ease of use of HBM technologies is a direct result of its world-class development process, expertise and in-depth experience of a broad range of industries. nCode product development is ISO9001 certified. Product support is available through HBM-nCode offices in Europe, North America and Asia.

For more information, please visit our website at www.hbm.com/ncode or find 'hbmncode' on:

