Timken Addresses NVH Requirements in Bearings

Matthew Jaster, Senior Editor

As NVH technology advances, so do the tools that allow engineers to study, test, and manufacture bearings capable of delivering high-performance and quality.

NVH data in the wind industry has led to educational and training opportunities for Timken.
All photos courtesy of Timken.

Everything is subject to variations during the manufacturing process, according to Dr. Desheng (Victor) Li, senior NVH engineering specialist at Timken. The geometry variations, in the form of waviness and surface roughness on ring raceways and rolling element body, are called manufacturing imperfections because all manufactured parts will naturally have some level of variations that cannot be eliminated.

When a bearing rotates, the manufacturing imperfections can excite the bearing to vibrate and radiate sound into its surrounding environment. Compared with the manufacturing imperfections, however, the damage such as dents and spalling on bearing components and lubricant contamination are typically the major sources for most significant bearing noise and vibration in applications.

Timken has developed and applied advanced NVH simulation technology to help make bearings quieter and more precise. The following article will discuss how this technology has evolved in recent years and how it might change in the future to meet the increasing demands in the marketplace.

Application Advantages

"How quiet is the automobile today versus what we deemed was acceptable 10, 15, even 20 years ago?" asked Brian Ray, chief engineer-industrial at Timken. "With the evolution of the electric vehicle, the entire drivetrain (every piece of rotating equipment) needs to be quieter to accommodate today's NVH quality standards."

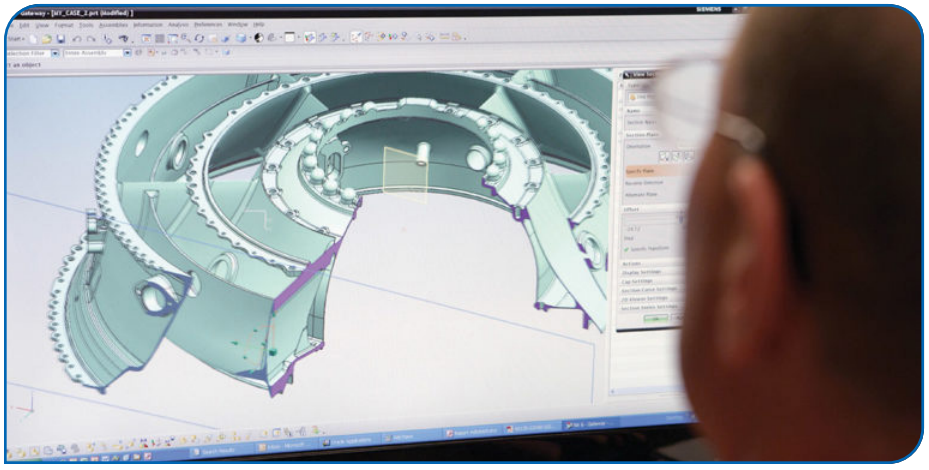
Ray cites the increase in condition monitoring as a significant factor in the growth of NVH tools in 2020. "Engineers are adding more sensors to their equipment while proactively monitoring the signals and the component data. Vibration is typically one of the signals to focus on in condition monitoring," Ray said.

Industries like automotive, paper, and wind have led the way in recent years allowing engineers to examine bearings in diverse applications and environments. Ray said that the NVH data in these areas has led to educational and training opportunities and prepared Timken to better understand how to keep bearings running at the highest and most efficient levels.

"Vibration needs to be considered for all machine tools—whether it's a grinding, milling, or drilling process—in order to create tighter part tolerances," Li added.

The changing requirements in the automotive industry will lead to new NVH tools and resources as more hybrid and electric drivetrains replace the internal combustion engine.

"In many cases, customers are concerned about noise-causing vibration that could lead to performance challenges in the larger system," said Li.



CAD view of a bearing.

> "The challenge is to design bearings that not only meet performance requirements, but also can be manufactured with a competitive cost," said Dr. Desheng (Victor) Li, senior NVH engineering specialist at Timken."

The vibration of rotating equipment can also impact the performance and appearance of the finished product as well.

"Another example is the flat rolling of products in the metals industry. Any variation or vibration of the rotating rolls can translate into the finish rolled product, making it visually unacceptable. Applications like automotive body panels and appliances are sensitive to surface variations. Timken has helped our cold-mill customers to solve mill chatter issues so that they can produce aluminum sheets qualified for automotive applications," Li added.

Bearing NVH Research

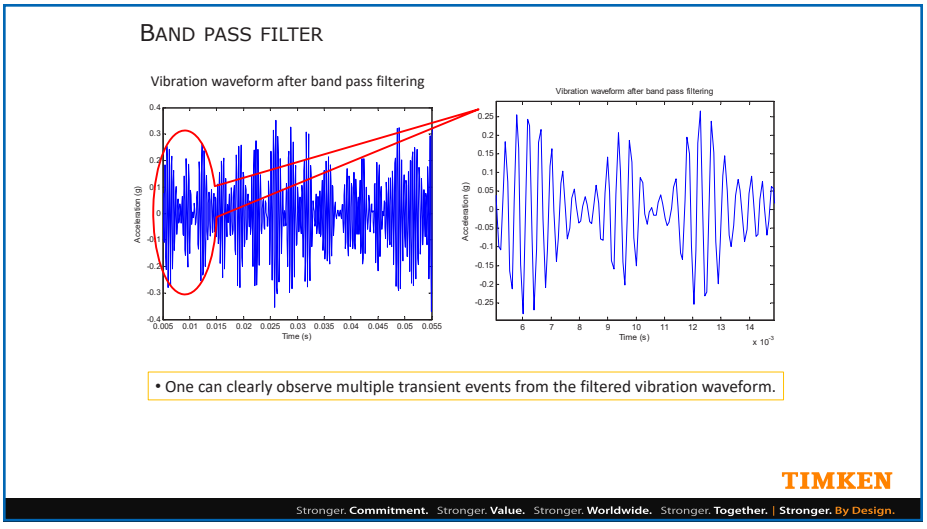
There are four major driving forces behind NVH research. The first one is the increasing demand for quiet products, such as passenger cars and home appliances, from consumers; the second one is that vibration can affect the quality of the product produced by a machine such as machine tools and cold mill stands; the third one is the tightening government regulations on environmental and workplace sound levels; the fourth one is that some customers use bearing sound and vibration as an indicator of bearing quality and life.

Although noise and vibration can be an indicator for bearing damage, there is no solid scientific evidence yet to support the correlation between the sound and vibration generated by typical manufacturing imperfections and bearing life.

"The challenge is to design bearings that not only meet performance requirements, but also can be manufactured with a competitive cost," Li said.

Without simulation software, engineers are forced to go through multiple iterations by making the physical prototypes, putting them on a test rig, and measuring the NVH. The process lengthens product development time and increases cost.

"Historically, I would say physical testing has been the benchmark and industry standard for measuring and trying to improve the NVH performance of bearings," Ray said. "In order to prove the performance increase, you have to physically test the bearing and then review the data with your customer."



Bearing damage diagnosis using envelope analysis.

Recent innovations on the mathematical and modeling side have changed things.

"The vibration of a multibody system is extremely complex, so it's difficult to model and takes a lot of 'computer horsepower.' In recent years, we've seen great improvements in analysis software and NVH performance can now be simulated in some industries virtually," Ray said.

The Virtual Sound Test System

Even with the significant improvement in commercial simulation software and computer power, it is still a big challenge to conduct bearing NVH simulation because thousands of contacts need to be simulated when a bearing rotates. It could take days to conduct one simulation if a FEA or multibody dynamic commercial software is used. To tackle this challenge, Li developed Timken's proprietary bearing NVH simulation software called *VSTS (Virtual Sound Test System)*. Thanks to its sophisticated algorithm, *VSTS* runs much faster than the commercial software, making it feasible to be used as a design tool.

"This software tool takes the whole system into account," Li said. "It can predict the system-level vibration not just of the bearing. The system dynamics of a gearbox, for example, may amplify the bearing vibration at system natural resonance frequencies, so it's extremely important to include system dynamic properties in the simulation."

In addition, *VSTS* allows Timken engineers to work with OEM designers at the earliest stages of product development. "We can simulate all of the design features of a bearing," said Li, "rotating at different speeds or under different load conditions. We can simulate conditions with outer ring rotating or inner ring rotating."

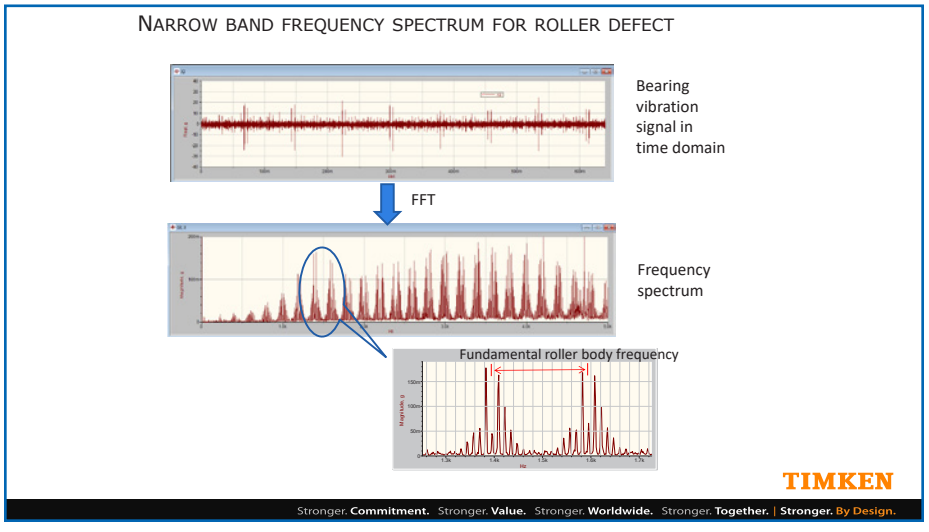
Modeling can also be used to simulate damage that may occur in service. *VSTS* has been thoroughly validated with test results. Li used measured waviness, surface roughness, and dent size as input in *VSTS* for simulations. He then measured the vibration of the bearings and used the test data to validate *VSTS*.

One of the successful applications of *VSTS* was to develop manufacturing specifications for a customer application. One customer had requested strict specifications for every bearing component—from the inner and outer rings to the individual rollers. The Timken sales and customer engineering teams worked with R&D to run *VSTS* simulations for the scenarios that the customer was designing for. They presented the resulting data as proof that Timken's proposed alternative specifications would have the same or better NVH performance than the one the customer had originally requested without as many tolerance restrictions.

In addition to the advanced simulation capability, Timken's sound test equipment is capable of testing bearings of various size from small automotive to larger industrial bearings, and of various types from tapered, cylindrical, and spherical roller bearings to ball bearings.

Furthermore, the NVH Lab has portable sound and vibration measurement equipment which can be brought to customers' site for on-site measurement and analysis to identify where noise and vibration are coming from.

"We've come a long way in both simulation and testing technologies," Li said.



Narrow band frequency analysis.

Artificial Intelligence and the Future of NVH Analysis

In the not-so-distant-future, Li believes the time will come when VR can be utilized in the computer simulation. "I see virtual reality as another tool for product development," Li said. "Bringing the customer into a virtual environment and letting them hear the sound and feel the vibration that a bearing makes in a system would be really impressive and more intuitive than a bunch of data and charts."

Another growing area is artificial intelligence (AI). Ray said that NVH today is a manual process where a piece of equipment collects vibration measurements and then engineers take this data, troubleshoot the problems, and come up with potential solutions.

"Basically, the condition monitoring system examines a signal to determine if things are running smoothly. You may get a green light if everything is working properly or a red light if something is wrong. This is where we're at in 2020," Ray said.

In the future, Ray believes AI will become advanced to the point where the machine itself will examine the data, identify problems, and fix these issues automatically.

"We're already seeing a pull in this direction across manufacturing," Ray said. "We may soon get to a point where the machine will interpret and identify bearing issues without any human interaction whatsoever." **PTE**

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