A VEXTEC CASE STUDY: A New Model for Gear Prognosis

This is a photo of the gear shaft example. In order to properly simulate the processing grain arrangement complexities, the physical part was sectioned as shown. High resolution imaging is used to statistically evaluate these complexities during simulator preparation work.

OVERVIEW

Gears are among mankind's oldest mechanical devices, and they continue to play critical roles in a myriad of applications from the esoteric to the mundane. For decades, accepted industry methods for predicting gear health have been adequate. But that's changing. Gear performance requirements are pushing the design envelope and now require more sophisticated modeling capabilities than what the standard AGMA methods can deliver. In this case study, helicopter gears are profiled, but the VEXTEC durability simulation approach will benefit all types of gears in a broad range of applications, from on & off highway vehicles to aircraft to wind turbine energy production, and more.

THE PROBLEM

Traditional industry approaches to gear health prognosis have focused on gathering physical data test points and using FEA stress models to predict a "Go-No-Go" threshold. But today, gear designs in critical applications like aerospace are seeing unpredicted failures because traditional, empirically-based AGMA methods do not predict the full range of performance, durability or failure. Furthermore, they do not differentiate for various damage mechanisms, nor do they provide a quantitative analysis in predicting the risk of failure. Finally, because they focus on stress modeling and test results, and not on the explicit physics material response to that stress, these methods assume that stress alone drives failure. They ignore the fact that not all gear designs fail according to their FEA models, and do not take into account the material's varying response to the stresses it is subjected to.

The current state of the art is also expensive and time-consuming, relying on physical testing to determine gear fatigue life. Actual hardware testing can run as high as $10 million for the physical identification of gear faults. No one can afford the money required to physically test the complete range of in-service applications possible; therefore engineers are forced to build in design margins or knock-down factors (often as high as 10X), which add weight, restrict operating performance, reduce efficiency, and raise operating costs. Considering that gear applications in every industry are calling for greater efficiency by increasing torque density, while reducing size, weight and cost, or operating in more severe environments, more sophisticated and accurate gear durability forecasting is needed now more than ever.

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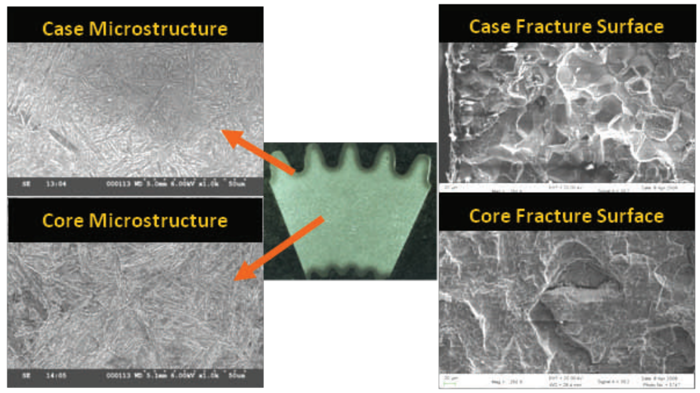
* For instance, in 1999, of the world total 192 turbine helicopter accidents, _28 were directly due to mechanical failures_ with the most common in the drive train of the propulsion system, according to *FlightGlobal's* Safety Expert, David Learmount.

VEXTEC



Actual gear manufacturing creates a complexity of grain microstructure arrangements that are ignored by the standard AGMA modeling approach. As shown grain arrangement differentiations create variations in fracture mechanisms which are accurately reflected with VLM simulation results.

THE SOLUTION

VEXTEC has developed a more accurate, cost-effective approach to gear life forecasting, based on its Virtual Life Management (VLM) technology. VLM simulations are built on a computational framework that utilizes physics-based material micromechanics to predict the damage state, and a probabilistic approach to variability to accurately quantify the risk of gear failure. This approach addresses key factors that the standard AGMA approach overlooks, namely, the variation in the material microstructure; how individual damage mechanisms combine to produce material degradation; an evaluation of stresses at the material microstructural level where damage ultimately originates rather than at the standard component level; and the variations in the manufacturing process, operating conditions and applications in use.

THE RESULTS

VEXTEC's gear life simulation builds on the intrinsic material properties and probabilistic reactions to extreme variability in material, manufacturing and usage. From analysis of the material microstructure and its reaction to the stresses – a higher order of computation processing than previously available, and certainly at a higher fidelity than is possible from test points in a historically derived empirical database – VEXTEC simulations can offer a number of new and valuable insights, quantified in the table below.

	Method	In-Service Case	Analysis Results	Comments
1	Conventional AGMA Analysis	Design Mission	**0 failures at 10^7 cycles**	System is 100% reli-able- no failures in any component of the system
2	VEXTEC VLM Simulation Result	Design Mission	**4% failures at less than 10^7 cycles**	96% system reliability - 4% failures of the gearbox shaft
3	Conventional AGMA Analysis	Field Mission	**Limited Life**	At 300, 000 cycles, reliability is 100%; at 10^7 cycles, reliability is 40%
4	VEXTEC VLM Simulation Result	Field Mission	**Limited Life**	At 300, 000 cycles, reliability is 90%; at 10^7 cycles, reliability is 0%

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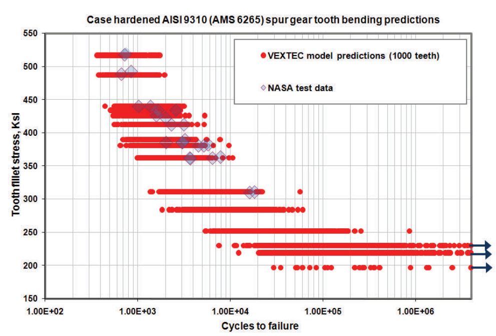
The insights provided by our VLM technology were derived in 90 days for two different in service conditions. In each case, a fleet of 300 helicopter gearboxes were virtually simulated.

The simulators were exercised through one million flight cycles to determine in service durability. Under design mission conditions, the AGMA model predicts no failures at one million cycles, indicating that the design is sound and no failures are expected. Since a high number of gearbox failures had actually occurred in the operating fleet, the AGMA approach is clearly not an accurate forecasting means. However, when the VEXTEC simulation is exercised, the gear fails 4% of the time. Similarly, when the systems are run under a more severe field mission, the AGMA approach predicts failures after 300,000 cycles, up to which point the reliability is 100%. However, the VEXTEC simulations predicts 10% of the fleet will fail at or before 300,000 cycles. The high number of actual field failures encountered in the operating helicopter fleet correlate well with our VLM technology predictions. For a fleet size of 300 helicopters, that 10% failure rate represents 30 helicopters whose gearbox failure could have been avoided through the use of VLM during design development.

VEXTEC simulations can help define the weak link in terms of reliability; what maintenance schedule should be adopted; and which specific components of the system could benefit from further engineering development, all of which are targeted to improve durability and reduce costs.

Using VEXTEC's VLM Virtual Twin™ gear simulator, for the very first time, gear durability predictions can be made on a cycle-by-cycle basis even before the first gearbox comes off the assembly line. This represents an important breakthrough in gear health prognosis, with broad based implications for commercial and military applications alike. In fact, this Virtual Twin gear simulator can be used in a range of applications in which there is any kind of aligned contact, anywhere two surfaces wear against each other, including bearings, from automobiles, to industrial machines, to wind turbines.



This compares 21 test points, collected over the course of a year, with 10,000 virtual simulations produced using VLM in one-fourth the time. The "scatter" at each load point is indicative of real life processing variations expected in a fleet of parts. As shown, 21 physical test points can't adequately convey this.

ABOUT VEXTEC

VEXTEC accurately, efficiently and economically predicts the performance, durability and true lifetime cost of a single component or an entire fleet—before they're ever built. Founded in 2000, VEXTEC has pioneered and patented innovations in material science and probability theory to form the foundation of its Virtual Life Management (VLM) technology. Manufacturing companies from such diverse industries as aerospace, heavy equipment, automotive, electronics, energy and medical implants can all benefit from VEXTEC's unique ability to predict product life cycles and failure, and most importantly, their financial consequences. To learn more, visit www.vextec.com.