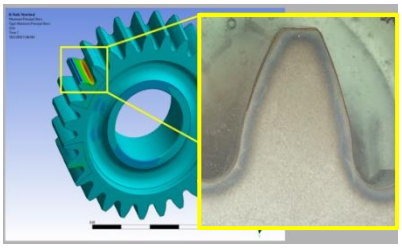
Virtual Prototype Durability Testing with VPS-MICRO®



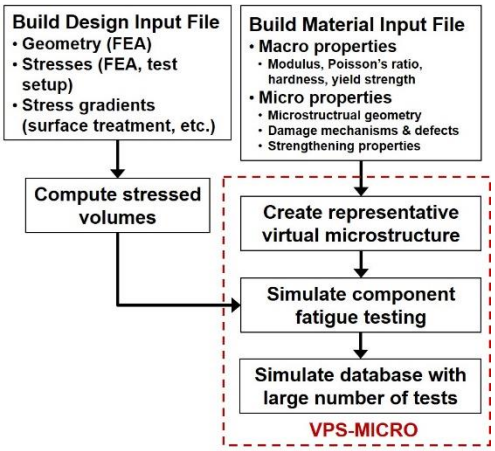
Changes to manufacturing processes have definitive effects on the performance of components. Here, changes to a gear's heat treatment/carburization and its shot peen characteristics were evaluated in a virtual design of experiments, before physical prototyping would even need to begin.

OVERVIEW

One of the costliest areas of product development is the testing stage. Even when considering the time and resources already invested in design and prototype fabrication, the testing budget can easily eclipse these. Coupon-level testing, subassembly testing, full-sized test articles…different usage conditions requiring their own testing regimens and protocols. And what happens when something fails in testing where it shouldn't have, or fails too early? The testing cycle repeats itself, with budgets quickly ballooning out of control after each iteration. This looming reality will often frustrate design teams and turn them towards more conservative designs. In a similar vein, designers wishing to evaluate material and process changes within established products in critical applications (for example, looking for less-expensive material grades that will still provide desired performance) are faced with the testing involved in requalification. VEXTEC's comprehensive service and software solution with VPS-MICRO® gives companies the ability to virtually build and test hundreds of different prototype designs, and quantifies the risk involved to pursue any of them in actual manufacturing.

THE PROBLEM

Eaton Vehicle Group (EVG), a global automotive supplier and main division of Eaton Corporation, was investigating multiple proposed changes to its manufacturing processes. Eaton provides transmission components (gears, bearings, etc.) with application-specific performance characteristics to meet needs in various markets. EVG wanted to quickly determine the effect of manufacturing process changes on fatigue durability of gears. Some of the manufacturing processes in their investigation impact the surface and in-depth residual stresses seen in gears (surface enhancement techniques like shot peening); other processes impact the material itself (the degree of carburizing heat treatment, and how much intergranular oxidation occurs in the microstructure). Since the processes are not specifically related (that is, changing the duration/intensity of the peening has no effect on how many oxidation sites there are near the surface, and vice-versa), it would be a large task to study the effects of these changes via physical testing. First, the parameters must be identified for each of the manufacturing processes (residual stress profiles, intergranular oxidation as a function of atmospheric carburization). Next, the extent of the parameter changes must be quantified, and a design of experiments (DOE) would be set-up. Then, coupon-level testing on the individual material/process interactions would be performed to collect baseline mechanical property data. Finally, full-scale component testing would need to be performed for each portion of the DOE. Evaluating what seems to be two simple manufacturing processes can become very intensive when one must consider all of the resources that testing demands. At the end of this DOE there might be one or two feasible choices for Eaton, or there might be none. However, these decisions would have to be made only on a handful of tests, often with only one or two tests being repeated at the same exact processing and testing conditions. Can the risk to part performance be truly quantified with such a small test population?



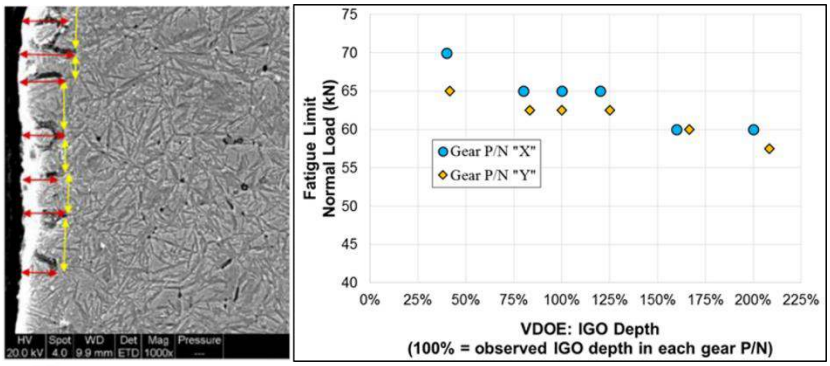
VPS-MICRO simulation workflow process.

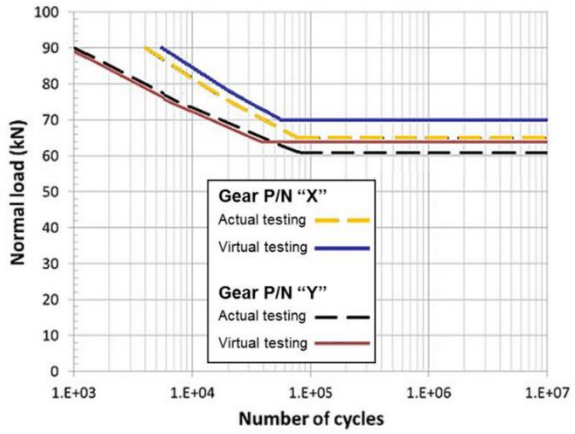
THE SOLUTION

Eaton partnered with VEXTEC to take advantage of virtual simulation technology. Over a short period of 8 weeks, VEXTEC's engineering team worked with Eaton to understand the material and design information already in-hand (material property data, finite element structural design files), and helped to develop material and stress models that appropriately captured the current-state of production, as well as the proposed variations. VPS-MICRO was used to simulate the testing of thousands of gears in a virtual DOE, providing a level of confidence and parameter sensitivity that could never be afforded with physical testing. Eaton now had the ability to independently, or simultaneously, pull different "levers" of their manufacturing process, and understand the risk to performance in making any/all of these process changes.

THE RESULTS

An example of the detailed virtual DOE output is shown below. The depth of intergranular oxidation from the surface was evaluated in terms of its impact on fatigue life of a vehicle transmission gear. Similar computational evaluations were performed for the surface enhancement processing options being explored by Eaton. These virtual studies were completed before physical prototype testing results were used to validate the technology. In this way, certain prototype designs could be evaluated as high-value and implemented in production more quickly; similarly, bleak prototype designs could be effectively dismissed without tying up valuable resources. The technology has helped Eaton evaluate different material suppliers for its multitude of transmission products efficiently and quickly, at a fraction of the cost it would take to complete the study using physical tests only.





Material and stress effects due to manufacturing process changes (intergranular oxidation, seen above) can be modeled and simulated in VPS-MICRO (stress-life curve, seen at left), creating a virtual test database of thousands of components. The risk of making critical process changes can now be quantified and better understood beforehand.

ABOUT VEXTEC

VEXTEC'S VPS-MICRO® software is a unique combination of engineering analysis, material science and condition monitoring protected by seven patents. VEXTEC helps companies predict and enhance the reliability and performance of critical components during design, manufacturing, testing, and service. Since 2000, we have provided solutions for hundreds of different products across many industries including aerospace, automotive, heavy machinery, medical devices, and energy development.