AEROSPACE FIRM DETERMINES ROOT CAUSES OF BEARING FAILURE WITH ROBO-MET.3D®

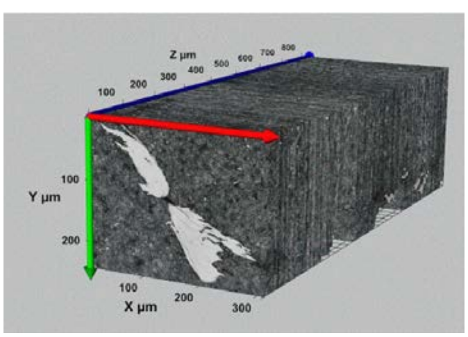
CASE FACTS

About 34% of all premature bearing failures are attributable to fatigue, according to Acorn Industrial Services.

Fatigue-induced degradation of the starting microstructure, and other factors can lead to catastrophic failures, or at the very least, increased costs due to short part lives in highly loaded aerospace bearing applications.

White etching regions (WERs) and “butterfly formations” are seen in subsurface stressed regions these bearing elements, as well as around inclusions that can cause these failures.

Serial sectioning using Robo-Met.3D helps bearing professionals identify and analyze these root causes for bearing element failure, and to prevent future failures.

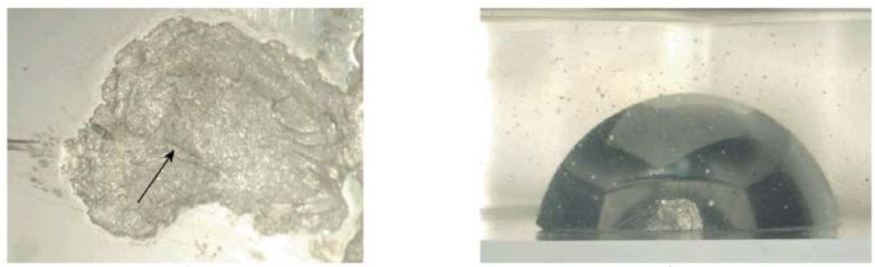


A stack of 15o serial sections of spalled M50 bearing collected by Robo-Met.3D®. A ceramic inclusion at the center of this formation was the cause of failure.

SKF AEROENGINE HAD A CHALLENGE

SKF was notified by a customer that several commercial jet turbine main-shaft engine bearings had been removed from service prematurely. An alarm was activated in the early stages of each event. This minimized damage to a single spalled ball in most cases.

Fig. 1a- Spalled area in VIM-VAR AISI M50 ball; 1b- mounted sample for serial sectioning.



a) b)

The spalled ball had a unique linear indication running parallel with the raw material grain flow. SKF suspected that there was an inclusion causing this. However, the inclusion material was lost when the samples were prepared using conventional 2D metallographic techniques.

SKF needed to present evidence to their material supplier that the bearing failures were caused by subsurface inclusions. One ball was selected for serial sectioning analysis using Robo-Met.3D®, having a spall with a linear indication that went subsurface (Fig. 1a).

The motivation for this study was to present evidence to the material supplier that the bearing failures were caused by subsurface inclusions.

ROBO-MET.3D® SERVICES HAD A SOLUTION

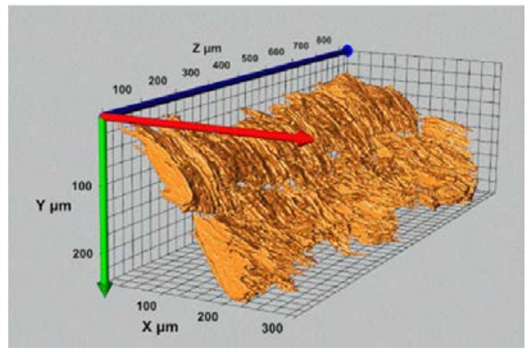
Serial sectioning using Robo-Met.3D® automatically grinds and polishes material from a sample layer by layer. The sample is ground, polished, optionally etched, and the layered sections are imaged using optical microscopy. The images can be aligned and analyzed to create a 3D dataset.

SKF’s sample was mounted for metallography. Knowing the orientation of the linear indication allowed the sample to be mounted with the feature ideally positioned for serial sectioning (Fig. 1b). The sample was polished using a series of 6 μm/3 μm/0.25 μm diamond abrasives, followed by finishing with DI water and 0.05 μm colloidal alumina solution. Samples were etched with 2% Nital solution for contrast.

About 150 sections, or slices of data were collected for this sample, at an average separation of 5.6 μm. Imaging was performed using a 50× objective and 1× optivar. The resultant spatial resolution is approximately 0.21 μ in both x and y. The 2D image tiles from each layer were stitched into 2× 2 montages, and registered with the images from the next layer using Fiji and Image Pro Premier software suites. The reconstructed data set had dimensions of 300 μm ×300 μm ×840 μm along length, width and depth. Fig. 2a is a 2D image, and 2b is an image of the segmented butterfly feature in 3D.

Fig. 2a- Typical 2D optical micrograph of butterfly and initiating inclusion.

Fig. 2b- 3D rendering of segmented butterfly feature in M50 ball.



ROOT CAUSE ANALYSIS– THE INCLUSION IN THE BUTTERFLY

An inclusion was identified in the butterfly formation (Fig. 2a). Segmentation helped to isolate and identify the non-metallic inclusion in the spalled ball. The inclusion proved to be sizable, and extended through the butterfly region (Figs. 3a, b). The feature was traced for over 400 μm. The elongated morphology matches two classifications as defined by ASTM E45, Type A-Sulfides and Type C-Silicates. This provided the required evidence.

Fig. 3a- 3D image stack of sections showing inclusion in relation to the butterfly region.

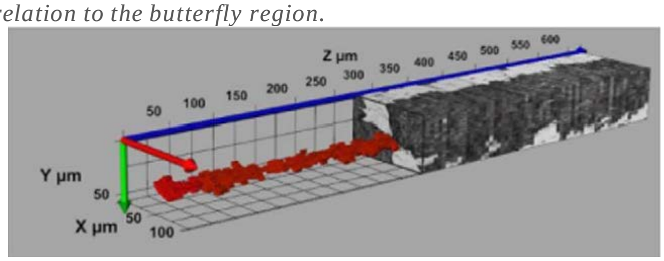
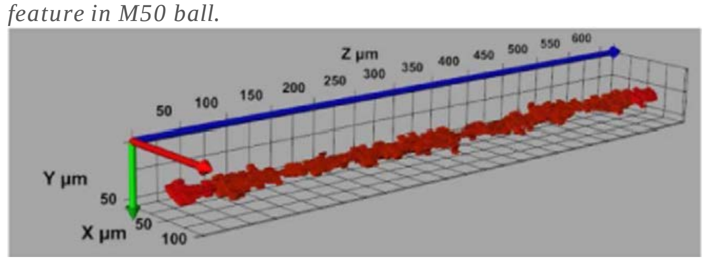


Fig. 3b- 3D rendering of the inclusion in segmented butterfly feature in M50 ball.



CONCLUSIONS

The Robo-Met.3D system produces a comprehensive scale of analysis that is orders of magnitude larger than is practical in FIB/SEM serial sectioning experiments. The technique was useful for investigating a failed component from the field and determining the root cause. Due to the large sampling volume, a butterfly feature formed on an elongated inclusion was traced for over 500 μm, achieving the study objective.

A comprehensive analysis including this case has been published jointly by UES, AFRL, and SKF as Ganti, S., Turner, B., Kirsch, M., Anthony, D., McCoy, B., Trivedi, H., & Sundar, V. (2018). Three-dimensional (3D) analysis of white etching bands (WEBs) in AISI M50 bearing steel using automated serial sectioning, Materials Characterization 138 (2018) 11–18, and is available at www.ues.com.

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