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Counting on Fatigue –Striations and Their Measure

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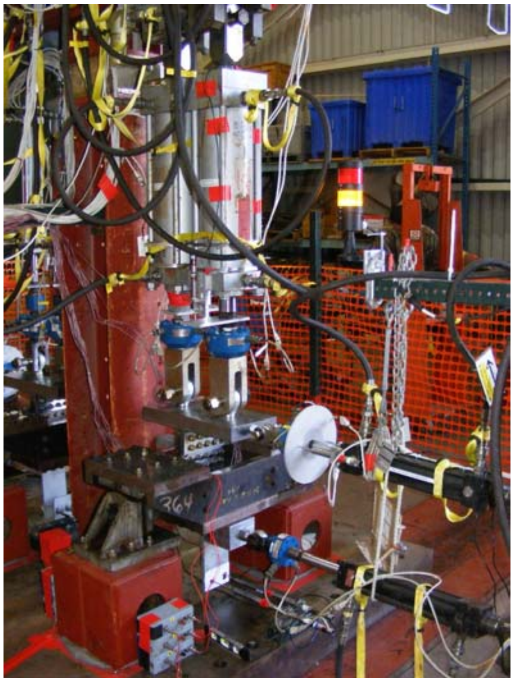
Fatigue has been the subject of innumerable books, papers, and studies since the late 1800's and continues to be a major factor in component failure with an estimated 90% of all mechanical failures being attributed to fatigue. The classic fatigue "thumbnail" often visible to the naked eye may allege fatigue, but microscopic striations - tiny ridges that bear immutable witness to cyclical loading – pronounce the verdict. As such, counting striations should provide the analyst with valuable information regarding the loading regimen, the time to failure, and insight into events that gave birth to fracture. This paper presents both pros and cons of striation counting, discusses striation count accuracy, and provides lab tested techniques for generating striation counts.

Given the many factors which impact count accuracy, questions regarding striation count accuracy are expected. Recent testing performed by The Boeing Company on a titanium tee section (Figure 1) sheds some light on that subject. The experiment was designed to gather crack propagation data and determine the number of cycles required to initiate fatigue cracking. By subtracting the number of cycles determined by striation counting from the total number of cycles applied, an estimate of the number of cycles to crack initiation could be obtained. This estimate was augmented by acoustic emission techniques designed to record the time at which cracking began. When results from the titanium fatigue testing were compared, predictions from the two methods (acoustic emissions and striation counting) differed by as little as 0.6% to as much as 22%. Given the inexact nature of striation counting, variations of up to 20% were considered reasonable.

The paper discusses striation counting techniques for mixed mode regions, spectral loading, poorly defined striations, and repetitive spectrum loading (Figure 2), as well as obliterated origins and false striations. Examples of striation counting, count interpretation, and customer communication will be provided.

References:
1) George E. Dieter, "Mechanical Metallurgy", 2nd Ed., McGraw-Hill, 1976, p. 403
2) J. M. Barsom and S. T. Rolfe, "Fracture and Fatigue Control in Structures", 2nd Ed., Prentice-Hall, Inc. Englewood Cliffs, N.J., 1987, p.1
3) Boeing Metallurgical Laboratory Case Sheets 182020 and 313796



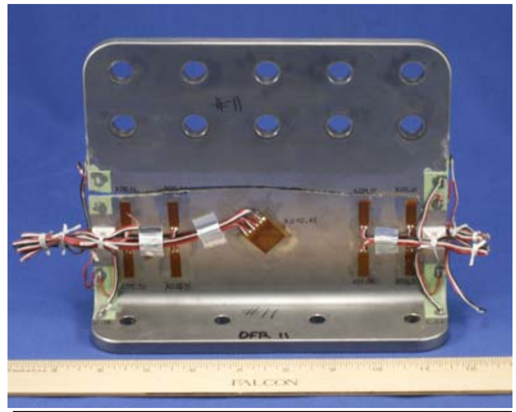
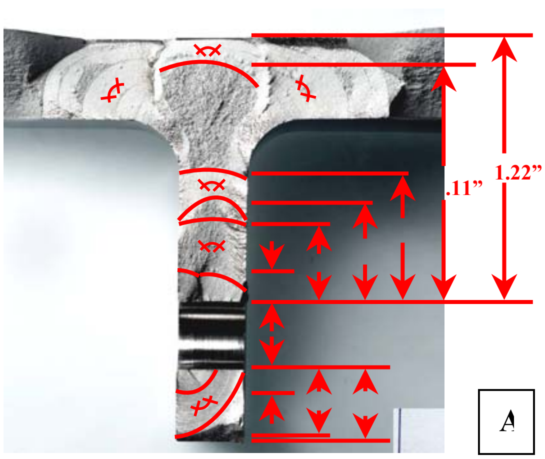
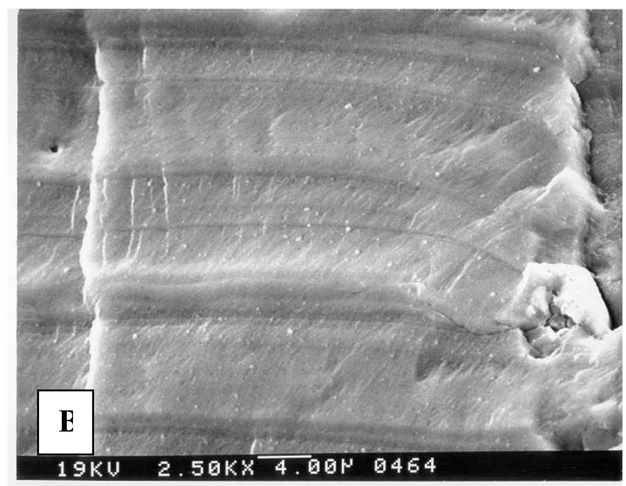


Figure 1 – Large actuators on the testing rig (left) apply tensile, bending and/or compression forces while horizontal actuators apply shear and bending loads to the test specimen (above) simultaneously.





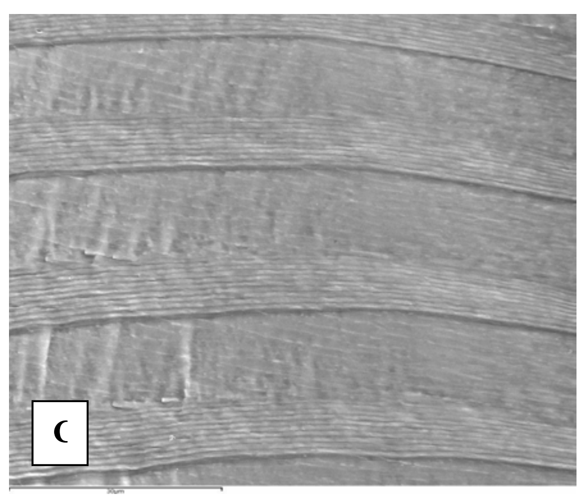


Figure 2

A) Example of counting through a fracture that exhibits striations mixed with dimple rupture (i.e. mixed mode) zones

B) Typical slow growth fatigue under spectral loading exhibiting regions of rubbed and oxidized striations

C) Counting fatigue striations in a material subjected to repetitive spectrum loading

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