IMPROVEMENT OF A FREE-FREE VIBRATION BENDING FATIGUE TEST

Onome Scott-Emuakpor
Aerospace Systems Directorate
Turbine Engine Division

BACKGROUND: The novelty of additive manufacturing (AM) continues to grow in the turbine engine community. Associated with this growth is the increased complexity of assessing structural integrity of specific manufacturing processes. For example, AM processes such as laser and electron beam powder bed fusion provide unrivaled feasibility for manufacturing thin, turbine engine flowpath structures that improve performance of small/medium scale propulsion and support the Air Force initiatives of low-cost and rapid development technology. However, empirical fatigue characterization using operation representative stress states is difficult with conventional test methods. Axial fatigue testing is conducted with low frequency (<100 Hz) mechanical loading and a non-representative stress state, and the well-publicized variants of vibration-based bending fatigue, though high frequency with representative stresses, are optimized to test 3.2 mm thick specimens. Since desired AM thin structures can be 0.2-0.5 mm for structures such as heat exchangers or cooled turbine blades, a new test method is required to accurately assess fatigue behavior. Consequently, a free-free bending fatigue test has been developed as a means to safely accept thin AM parts for improved small-scale turbine engines.

PROBLEM STATEMENT: The free-free vibration-bending test operates as described in the following two steps. First, simply-support a beam specimen at one of its 1st flex free-free nodes with a fishing line then secure permanent magnets on the opposite end of the specimen. Second, excite the specimen by surrounding the permanent magnet end of the specimen with a magnetic field activated by alternating current through a helical copper stock. Despite successful demonstrations of the free-free bending fatigue setup, there exists some inconsistencies in the modular setup that make specimen loading tenuous and continuous testing of specimens to failure fickle. A few specific areas of variation are as follows.

1.) tension in the fishing line
2.) positioning of permanent magnets (and entire specimen setup) in the electromagnetic field
3.) design/material choice of plastic tabs for modular attachment between specimen and fishing line

There is one commonality with the mentioned variations in the free-free test setup: human error. Based on this identification of the problem, two questions require answers.

1.) Is there an opportunity to improve the design of the fixture connecting the fishing line to the test specimen?
2.) Can any of the setup process be automated: e.g. a stage to move the electromagnetic coil, automated tension application with the fishing line, etc.

See an image of the test setup in the figure below.

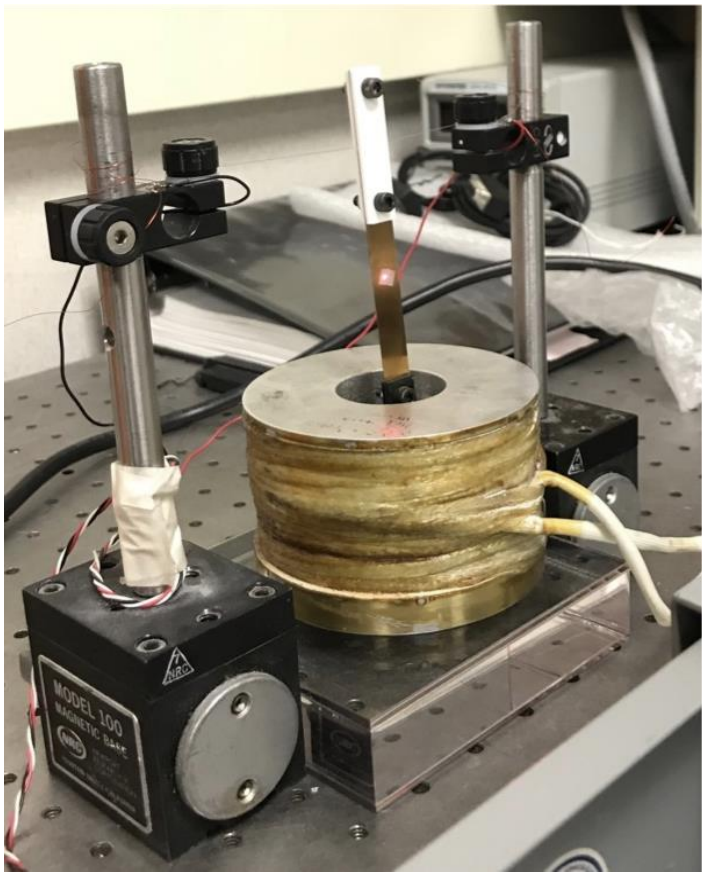

Figure 1. Free-free fatigue test setup

PROJECT GOALS: There are three main constraints regarding the free-free bending test. First, the beam test specimen must be simply-supported at a nodal line. Second, permanent magnets are required on the other end of the specimen. Third, a magnetic field is necessary to excite the setup. Absent of these three things, there is flexibility to selecting the solutions to the problems mentioned in the Problem Statement section. Furthermore, this project provides equal opportunity for computational and experimental activities. For example, improving the design of the fixture connecting the fishing line to the test specimen could require a great deal of computational work to minimize stress concentration on the test specimen while allowing for first bend flexure and being structurally sound. Understanding the remaining variations calls for more hands-on applications with the potential of supplementary analytical or computational work.

Success for this project is not a definitive metric. Simply studying and quantifying the effects of the existing variation provides benefits to the Air Force. This project serves as part of the journey for the development process of a test method that could be standard in support of the low cost, small-scale, rapid development initiatives that the Air Force has identified as key areas of technology in the next ten years.

CONTACT INFORMATION:

Onome E. Scott-Emuakpor, Ph.D.
Senior Aerospace Engineer
Aerospace Systems Directorate (AFRL/RQTI)
1950 Fifth Street, Bldg. 18D
Wright-Patterson AFB, OH 45433
Voice: 937-255-6810
Fax: 937-656-5532
Email: onome.scott-emuakpor.1@us.af.mil

Dino Celli
Aerospace Engineer
Aerospace Systems Directorate (AFRL/RQTI)
1950 Fifth Street, Bldg. 18D
Wright-Patterson AFB, OH 45433
Voice: 937-656-5530
Fax: 937-656-5532
Email: dino.celli.1@us.af.mil