Ultrasonic Fatigue : pulse-pause mode to obtain gigacycle fatigue life for metallic and composite materials

Supervision

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Gigacycle fatigue, Piezoelectric machine, Pulse-pause mode, Self-heating, Metallic materials, Composite materials

Abstract of the PhD project

In order to obtain life cycle for a material submitted to cyclic mechanical loads, researchers can use ultrasonic machines at high frequency (~20 kHz) [1] for reasonable duration of tests. This kind of experimental set-up allows to have in a short time, an evaluation of the material's fatigue strength up to a billion of cycles. There is a great interest of the industry in knowing and improving fatigue life in particular in the context of sustainable development for the sake of environment preservation. There are nowadays only four different systems worldwide (Japan, Italy, Germany and France), and the LEME has an agreement with the French company 3R.

However, this very high frequency tests induce self-heating for some materials and material properties could be modified until an early failure of the specimens, if the temperature is not

controlled. Thus, despite of the demand, these experimental set-ups are not widely used because there is no standardization nor norms as the test is material-dependent. A recent European project, FreqTigue [2], was dedicated to the influence of cycling frequency on fatigue strength of metallic materials.

The objective of this PhD thesis is dedicated to the evaluation of a new driving mode, called *pulse-pause*, in which periodic stops are introduced in order to control the self-heating phenomenon. This procedure increases the duration but it can allow to eventually define a normalization as the tests become independent of the tested materials. In the last conference on Very High Cycle Fatigue (VHCF7 [3]), there were less than 10 articles (out of 94 contributions) on this driving mode, but no comparison is yet available in the literature between continuous pulsation and pulse-pause mode.

The machines available at the LEME allow to introduce different loading conditions: tension/compression, tension/tension, torsion, and bending. For metallic materials [4, 5], all the loads can be tested and we will start by the most classical one, tension/compression (R-1). For composite materials, bending can be used [6].

The first part of the PhD is dedicated to the state-of-the-art analysis on pulse-pause mode in the open literature, with special emphasis on the experimental set-ups, parameters of the tests and materials.

Choice of the materials (metallic and composite) will be done in a second step, considering the self-heating sensitivity and the load level, in order to compare fatigue strength and duration of the tests.

A first experimental campaign can then start using both driving modes, continuous and pulse-pause, beginning with some self-heating tests and increasing the load level. The evolution of the temperature can be measured by an InfraRed camera. The temperature measurement at the specimens' surface will be also employed for developing an automatic driving system controlling the duration of the pulse and the pause in a closed-loop. The second part of the experimental campaign allows to obtain the fatigue strength at 10_8 cycles for the selected materials.

Finally, fractography analysis will be used to understand the damage mechanisms in the gigacycle domain. Depending on the progress of the PhD, the candidate could also study the damage evolution during a test using an in-situ microscope.

References

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