Optical strain measurement system for fatigue testing

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Abstract. This presentation will present displacement controlled uniaxial fatigue tests performed with specimens made of the nickel-based superalloy Waspaloy. For that an optical system (non-contact) for displacement and strain measurements has been developed. The system is able to track specimen deformation via edge detection for use in the feedback control of the test machine. Optical methods have their own limitations of resolution and difficulties in application. This work will present a review of effectiveness for our case and potential for wider use.

Introduction

Advances in material testing equipment and techniques during the past 40 years have enabled the development of more realistic fatigue tests by applying loads representative of service life, at different temperatures and test frequencies. However, challenges remain for strain-controlled fatigue testing. Clip-on gauges (extensometers), for instance, have a fixed gauge length which can lead to significant errors at low strain conditions. Certain clip-on gauges require dimples in the specimen to be properly attached, which makes them unsuitable for use during fatigue testing because of the associated stress concentration. Electrical resistance bonded strain gauges are the most widely used method for obtaining surface strains from a component or specimen; however, the quality of the measurement is directly dependent on the quality of the bond and it may not survive long into the test. Moreover, bonded strain gauges only provide an averaged local measurement, corresponding to the region they are attached to. Aiming to overcome these limitations, an optical system capable of tracking specimen deformation via edge detection has been developed for controlling uniaxial fatigue tests.

Experimental work

Displacement controlled monotonic and cyclic tests are being carried out with Waspaloy at room temperature. The testing rig consists of a single actuator (capable of 100 kN) controlled by a CaTs[3] digital servo-controller. Hour-glass specimens with square cross-section are being used for the tests. They were obtained from the clamping region of cruciform specimens previously used in biaxial fatigue tests (for more information on the biaxial fatigue tests please refer to [1]). No plastic strain was observed in this region during fatigue testing. Thus, it is safe to assume that the material properties remained unaltered and that the region is suitable for manufacturing new specimens.

Figure 1 illustrates the hour-glass specimen and the region where they were manufactured from. The geometry of the clamping region and the clamping holes restricted the design of the specimen and of its gauge section, which is only 2mm long and 6mm wide. Waspaloy is a nickel-based alloy widely used in aircraft engine disks and designed to sustain extreme mechanical loads. This material is extremely hard and difficult to machine. Thus, the specimens were manufactured using wire erosion (EDM), which produced a smooth-surfaced gauge section with enough features for implementation of optical measurement methods.

For both tests (monotonic and cyclic) a Virtual Instrument (VI) coded in LabView is used for measuring displacement and strain. The VI is connected to the servo-controller as a transducer and configured for use as external compensation. This configuration allows the transducer (VI) to be used to provide a compensation feedback into the displacement control loop of the testing machine.

The material used in our tests came from the same batch as the one used by Pattison in his work [2]. Therefore, in order to validate the VI and the specimen design, the initial tests were set as to reproduce some of the results obtained by Pattison.

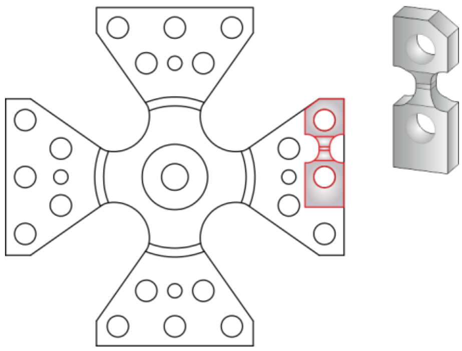

Figure 1 – Hour-glass specimen geometry.

Conclusions

Preliminary results confirm the accuracy of the proposed optical measurement system. It was observed that even for lower cyclic strain ranges the system is able to track deformation without excessive glitch in the measurement. It is concluded that the proposed system is a viable and effective alternative for strain-controlled fatigue tests, especially when strain-hardening plays an important role and the strain range must be readjusted during the test.

References

[1] J. Sahadi, R. Paynter, D. Nowell, S. Pattison, N. Fox, Comparison of multiaxial fatigue parameters using biaxial tests of Waspaloy, International Journal of Fatigue 100 (2017) 477-488.

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