In-situ monitoring of crack initiation and propagation for additive manufactured 316L stainless steel under fatigue loading

Cansin Ozdogan*[1], Bijan Mohammadi Sangjouey[1], and Mohammad Malekan†[1]

[1]Centre for Industrial Mechanics, Department of Mechanical and Electrical Engineering, The Faculty of Engineering, University of Southern Denmark – Denmark

Abstract

Fatigue cyclic loading is one of the most challenging fields in different industries, including automotive and aerospace industries. The lifespan and crack propagation of the metallic structures are still intriguing and critical topics. In this research, the lifetime and crack growth rate under uniaxial fatigue loading are being investigated for additive manufactured (AMed) 316L stainless steel. The samples are manufactured using a machine based on laser powder bed fusion. The central cracks are cut at lengths of 5 mm and 10 mm through the rectangular plate as a straight line and inclined at 45 degrees. These samples are subjected to uniaxial fatigue loading under different frequencies (10 and 20 Hz), stress ratios (R = 0.1 and 1) to investigate the fatigue and fracture behavior of AM 316L stainless steel material. During the loading, an infrared thermal camera is being used to record temperature variations and to capture areas where the heat is released because of plastic deformation and crack growth. Similarly, the crack extension versus time is recorded through a portable high-resolution camera to evaluate the crack growth rate under loading conditions. This advanced test setup is considered to present more controllable and practical way to generate S-N curves and calculate m and C coefficient values of the Paris law equation. Additionally, comprehensive microstructure studies are being carried out to discover and support multiple reasonings behind the fatigue failure mechanism. For instance, scanning electron microscope, electron backscattered diffraction, and ATEC profilometer are employed to illustrate the internal features such as crack initiation sites, crack propagation, final failure regions, lack of fusion, grain boundaries, solidification patterns, surface roughness and residual stress distribution. The porous percentage and void formation are monitored via an X-ray computed tomography equipment for different cycles by interrupting the experiment. As a result, the effects of crack geometry, frequency, stress ratio, stress amplitude, and surface roughness on lifespan and crack growth pattern of the AM material are enlightened in detail.

*Speaker

†Corresponding author: malekan@sdu.dk