

# Recovery of metal fatigue damage by electropulse technology

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## Abstract

Metals are vital to human society and have widespread uses across a broad spectrum of industries including but not limited to packaging, transport and construction applications. They are mainly used in load-bearing structural components. Nonetheless, they possess finite operational lifetime attributable to the dynamic interplay of environmental and mechanical stimuli, culminating in the generation of structural imperfections, deterioration, and the ultimate mechanical failure. It is estimated that metal fatigue is responsible for more than 80% of mechanical failure due to the existence of flaws such as cracks. Consequently, there is an imperative to pioneer advanced materials technology with the express aim of extending the operational lifetime of metallic components. This endeavour not only serves to increase material resource efficiency but also serves as a bulwark against environmental damage.

At Brunel University, our research is intently focused on the development of advanced material technology to recover fatigue-induced damage, specifically microcracks generated by cyclic loading. Our methodology involves the application of ultrashort current pulses at a frequency of 7.5kHz, with and without localised induction heating. Employing multiple pulses of high current density of upto 2.15kA/mm<sup>2</sup> to fatigued 316L stainless steel specimens has yielded the complete closure of microcracks with dimensions of upto 60µm in width and 1350µm in length. This crack closure is resulted from a synergistic mechanism involving localised melting and thermally induced compressive stress, all while preserving surrounding microstructure unaffected. The application of localised induction heating prior to electropulse treatment step further extends our capabilities, enabling the closure of wider microcracks with dimensions of 170µm in width and 700µm in length, at a reduced current density of 1.6kA/mm<sup>2</sup>.

This talk will give research highlights concerning the closure of fatigue-induced microcracks within 316L stainless steel through electropulse treatment. Furthermore, it will provide illuminating insights into the effective crack closure strategies using electropulse treatment. A comprehensive analysis will be followed, encompassing the modelling of temperature and stress distributions around the microcrack through finite element method (FEM), as well as a thorough microstructural characterisation of healed specimens using a combination of optical microscopy, scanning electron microscopy-electron backscatter diffraction (SEM-EBSDB), and micro/macro X-ray computed tomography (CT).

**Keywords: electropulse; crack healing; stainless steel; SEM-EBSD; FEM**

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