Abstract for the general public

Project title:

Modelling of fatigue in shape memory alloys: the interplay between intrinsic material behaviour and structural instability

Nowadays, polycrystalline shape memory alloys (SMAs), especially NiTi, are widely used in many engineering and biomedical fields. During the service life, SMA devices are often subjected to cyclic loading, thus a thorough understanding of the SMA fatigue characteristics is essential. The challenging aspect in the study of the SMA fatigue problem arises from the interaction between fatigue evolution, that is, functional degradation and fatigue crack formation, and martensitic phase transformation which is manifested macroscopically in a homogeneous or an inhomogeneous deformation mode. In a pseudoelastic NiTi under uniaxial tension, the transformation initiates with deformation instability in the form of localized martensite bands and proceeds by the propagation of diffuse interfaces that separate fully-transformed martensite and untransformed austenite regions. It is now well-recognized that propagating instabilities play a critical role in the fatigue behaviour of NiTi. More specifically, in view of the strong local strain variation within the austenite–martensite interfaces, large local stresses develop that accelerate the degradation of pseudoelasticity under cyclic phase transformation, as well as fatigue crack nucleation and eventual failure.

Although, recent studies have strongly promoted the research progress of fatigue in SMAs, there still remain many important and complex aspects that need to be explored in order to gain a comprehensive understanding of the problem. From a modelling viewpoint, the need for a new generation of models capable of describing the interactive evolution of fatigue and propagating instabilities in SMAs is paramount. Therefore, the main goal of the present project is to develop a new macroscopic modelling approach for the phenomenon of fatigue in SMAs based on the analysis of propagating instabilities. This is a novel modelling strategy that contrasts the conventional fatigue modelling strategy adopted in the literature, which simply relies on a homogeneous phase transformation. A set of new models will be developed within the project and will be applied to study various relevant problems in which propagating instabilities play a highly important role. In the first class of fatigue problems, the intertwined evolution of the functional fatigue and macroscopic phase transformation will be studied. The focus will be on NiTi specimens under cyclic uniaxial tension and under cyclic combined tension–torsion loading conditions. In the second class of fatigue problems, the functional fatigue studies will be complemented by structural fatigue analyses. In this respect, a modelling-based fatigue-life criterion for SMAs within the whole high-cycle to low-cycle fatigue regime will be formulated.