Development of Early Damage Mechanics

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Abstract. The classical damage mechanics approach establishes the link between the accumulated damage and the change of first order elastic properties, such as Young's modulus. This change typically becomes measurable with the accumulation of defects or discontinuities, e.g. micro- or macro-cracks, by which point the structure is approaching its final (failure) stage. However prior to the micro- or macro-crack formation stage, which can extent over 90% of the lifetime, the mechanical damage in polycrystalline materials is associated with the accumulation of local plastic deformations within the grain structure. It has been demonstrated previously that the higher-order elastic constants are highly sensitive to grain plasticity and plasticity-induced damage mechanisms e.g. creep and fatigue. Therefore, the change of these constants can be related to the early damage of materials and structures and provides early prognosis of residual structural life.

In this work, we utilise Rayleigh waves in the ultrasonic frequency range to measure the third-order elastic constants and link these constants to fatigue damage stages prior to crack formation. The outcomes of this study demonstrate that the experimental methodology can be applied in-situ, and can be integrated in Structural Health Monitoring systems. Such systems offer many benefits including the development of effective maintenance procedures and reduction of the risk of structural failures.