HSLU Hochschule Luzern

Technik & Architektur
Vertiefung Produktentwicklung & Mechatronik

Master-Thesis Mechanical Engineering

Structural Health Monitoring Qualification and Implementation for Aerospace Structures

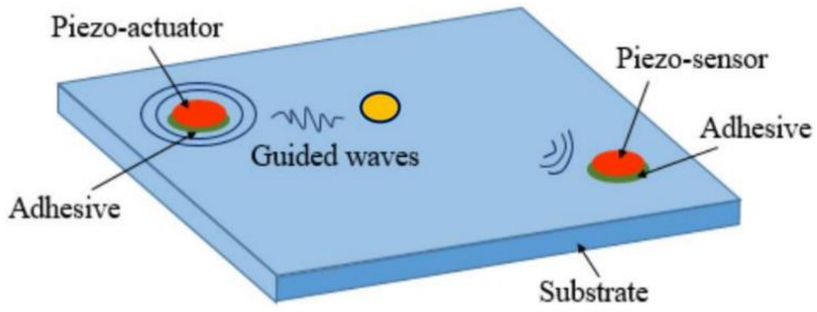

Figure 1: Working principle of a PZT SHM system using high-frequency guided waves.

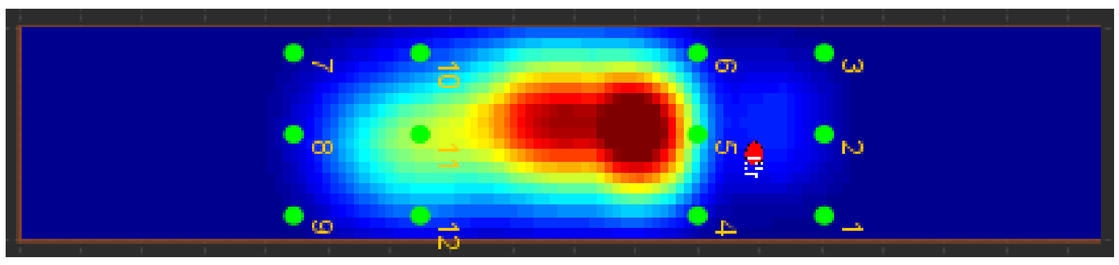

Figure 2: PZT SHM sensor system detecting fatigue damage in composite/metal stepped lap joint specimen.

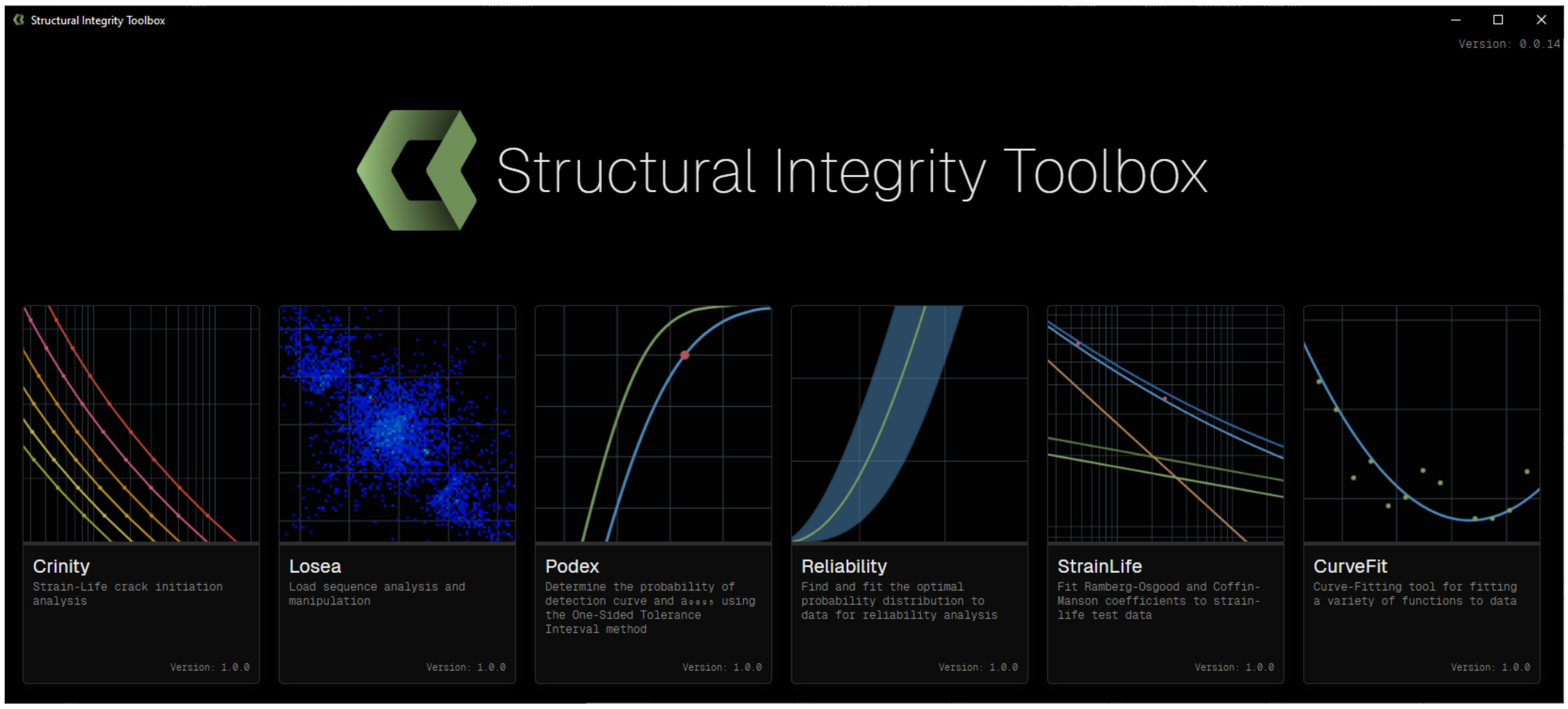

Figure 3: Launch-Window of the Structural Integrity Toolbox

Introduction

As safety-critical structures such as aircraft, bridges, and dams continue to age, the task of maintaining their structural integrity with non-destructive testing (NDT) techniques becomes increasingly demanding, increasing operational costs and leading to downtime. A promising solution emerging are SHM sensor systems, which employ the techniques of NDT to monitor a structure's health. The qualification and implementation process for a piezoelectric lead zirconate titanate (PZT) SHM system shall be demonstrated with a practical implementation example, where system performance testing in the lab is required.

Additionally, the management of structural health and structural integrity is a multi-faceted discipline, including:
- Statistical analysis of lab testing results to derive SHM system performance characteristics (Probability of detection curve (POD), $a_{90/95}$).
- Failure and damage modelling to predict the longevity of structural integrity and to determine critical structure locations.
- Analysis and handling of component usage data (e.g., spectrum loading data, mission profiles, wind gust distribution data, etc.), which can be used to inform the failure and damage models.
- Probability and variability modelling to aid in decision making and characterization of data for structural risk and reliability analyses and assessments.

These capabilities are best acquired with the aid of dedicated software tools, which shall be developed in the context of this thesis.

Procedure

To demonstrate the qualification and implementation process for the PZT SHM system, the following tasks were performed:
- Development of POD study test plan
- Critical design review of specimen design
- Specimen manufacturing and design verification through lab testing
- PZT SHM system training and familiarization lab testing

Results

A specimen design was developed and its behaviour under fatigue loading was successfully verified. The familiarization activities provided valuable insights for the continuation of the project.

A software toolbox was developed and has already proven to be a valuable asset in various other projects in the field of reliability engineering and fatigue analysis. More information can be found at www.crinity.ch.

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