# Large-scale Testing as a Precondition for the Development of SHM Systems

Herbert Friedmann*; Martin Kohlmeier**; Stefan Kremling*; Andreas Nuber*
*Wölfel Engineering GmbH + Co. KG, Hoechberg, Germany, 0049 931 49708-360/ 49 931 49708-650, friedmann@woelfel.de;
**Fraunhofer Institute for Wind Energy Systems, Hannover, Germany, 0049 511 762-17670, martin.kohlmeier@iwes.fraunhofer.de

**Summary**
This paper presents the continuation of the lecture Kohlmeier et al., Investigation of Degradation Process in Large Scale Experimental Tests by Structural Health Monitoring Techniques and Numerical Simulations. The mode of operation of a vibration-based SHM system for offshore support structures is described. The importance of the signal analysis is shown. The foundations for automated signal analysis must be investigated in large-scale tests.

## 1. Vibration based SHM Introduction

The main task of a Structural Health Monitoring (SHM) system and monitoring objective is to detect defective changes to the monitored object. However, there exists no sensor measuring damage. Structural Health Monitoring relies on the continuous measurement of physical quantities that change when the achievement of the monitoring objectives is compromised. For this purpose, with vibration based SHM-systems the dynamic behavior of the monitored object is constantly measured. This happens with accelerometers, temperature sensors and further specific sensors according to the monitoring task. Unfortunately, there is no one-to-one relationship between causes of changes in the structural behavior and their dynamic signal. For example, the natural frequency of a structure is lowered both with increasing mass and with loss of stiffness. Therefore, a detailed signal analysis of all modal measurement data is necessary and the characteristic vibration behavior has to be recognized. Another problem with vibration based SHM is that both changes in environmental and operating conditions (EOCs) as well as damage change the vibration behavior in a similar manner. The natural frequency of a rotor blade, which vibrates edgewise, drops when – after pitching – the vibration is flappwise. However, this change is due to changed operating conditions (EOCs) and not due to defective changes. Therefore, signal changes due to damage have to be distinguished reliably from those due to EOCs. This distinction is only possible by analyzing all modal data and identifying characteristic vibration patterns of damage and changes in EOCs.

## 2. Large-scale Testing as a Precondition for the Development of SHM Systems

The success of such SHM systems depends on their ability to detect all damage at a very early state (probability of detection) and to avoid false alarms (probability of false alarm). Another requirement is that an SHM system automatically detects all defective changes and works as autonomously as possible. For the development of the necessary algorithms as far as possible all probable damage signals and those of changed EOCs should be measured (see Figure 1). This is only possible in a controlled large-scale test, as we have successfully demonstrated within two projects, namely Underwater-INSPECT and QS-M Grout with its test setup depicted in Figure 2.

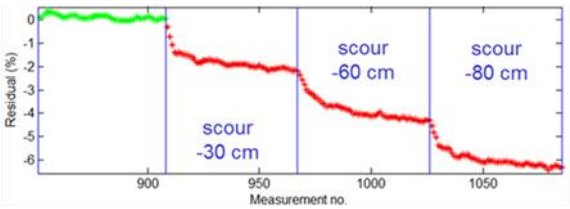


*Figure 1: Damage indicator for scouring*

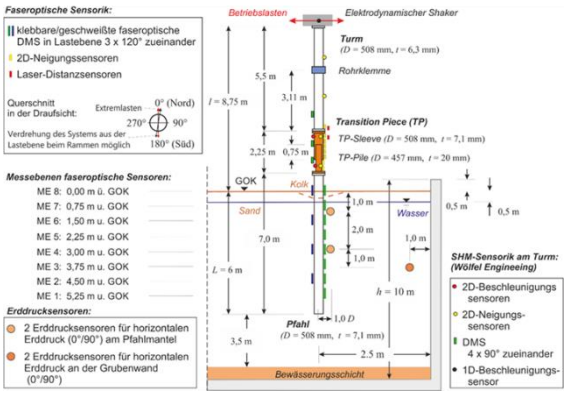


*Figure 2: Set-up and instrumentation of the monopile model in Test Center Support Structures, TTH, Hannover*