Extract from the annual report 2013
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LOAD MONITORING OF CRITICAL COMPONENTS IN ROTOR TESTING TECHNOLOGY

The push-pull rods of helicopters are the critical transmission link between the mechanical control system and the aerodynamically loaded rotating rotor blades. For this reason the loads occurring at these rods are continuously monitored during tests. This ensures prompt reactions at critical values, ramping down the system or modifying the test conditions to prevent overloads. A monitoring system of this kind based on a piezoresistive thin-film sensor has been developed at the Fraunhofer IST in collaboration with the Institute of Flight Systems (FT) of the German Aerospace Center.

Sensorized washer system for measuring forces in the push-pull rod

Since the mid-1970s the DLR-FT has been running its own rotor testing facility (RVS) for model rotors and complete helicopter wind-tunnel models which have been used successfully in numerous wind-tunnel tests. As part of the aviation research program (LuFo) funded by the Federal Ministry of Economics and Technology (BMWi) the DLR is trialing a new concept, patented in 2008, for active rotor control by means of a multiple swashplate system (META). Here special attention is due to the higher-frequency secondary control (HHC/IBC or higher-harmonic control/individual blade control) of the rotor up to approx. 70 Hz with the aid of actuator elements in the non-rotating system.

As critical, dynamically highly stressed components, the push-pull rods between the META control system and the rotor require constant monitoring. Until now this has been done by means of strain gauges which provide information about the prevailing load state from the elongation of the rods during operation. As a supplement to strain gauge instrumentation the Fraunhofer IST and the DLR-FT have jointly developed thin-film sensors tailored to this application. In addition to a better signal-to-noise ratio and integrated temperature compensation, the thin-film sensor system has the advantage that loads on the push-pull rods can be measured directly on the load path. Following the first tests of the new sensor system on the DLR's rotor test rig and in the wind tunnel, the thin-film sensors should in the long term replace the strain gauge system used to date.

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1 *The DLR rotor test rig with a sensor module from the Fraunhofer IST.*

2 *Fabrication steps in the thin-film sensor system from front to back: sensor module with electrode structures, a sensor module with a complete coating system, and a module with an electrically isolating coating on the back.*

Structure of the piezoresistive thin-film system

The thin-film sensor system takes the form of a multilayered structure. Here the first step in fabrication is to deposit a homogeneous piezoresistive DiaForce® coating by the PECVD process. To provide the electrode layer a chromium layer 0.2 µm thick is applied by PVD, structuring this by photolithography and wet-chemical etching. Finally, an electrically isolating and wear-protective layer is deposited which consists of a silicon- and oxygen-modified carbon coating (SiCON®). The individual process steps are shown in Fig. 2.

In addition, the connection surfaces are given a coating of copper. To create a bridge circuit in which two washers are placed on top of each other, a SiCON® coating is also applied on the underside to isolate the two washers electrically. This layering sequence has already been used successfully for sensorized washer systems.

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