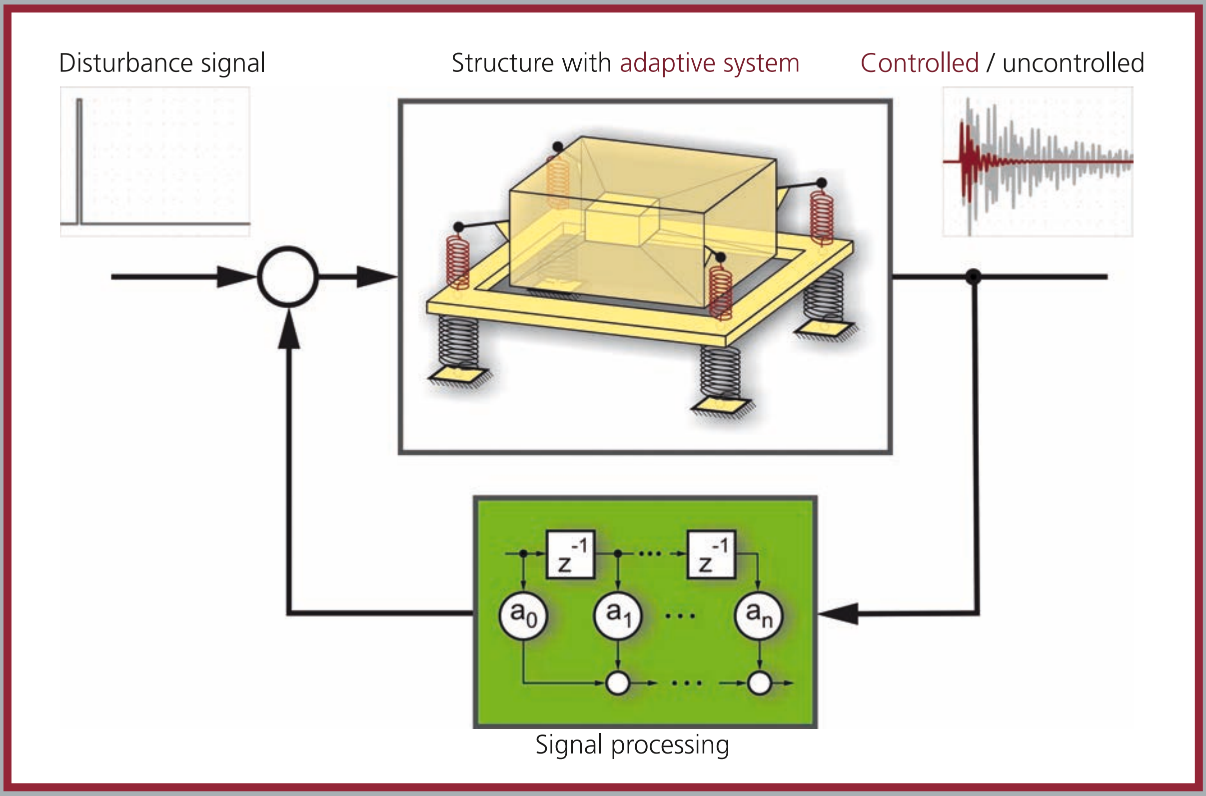
Fraunhofer
ADAPTRONIK

FRAUNHOFER ADAPTRONICS ALLIANCE

WHAT IS ADAPTRONICS?

Adaptronics is an active structure technology based on integrating sensor and actuator functions into mechanical structures. It aims at optimizing products by influencing mechanical structural properties in a controlled way. The focus is on active control of vibrations, noise and deformation as well as on structural health monitoring. For designing adaptronic systems, it is quite common to make use of multifunctional material systems (e. g. electromechanical transducers such as piezoceramics). Thus, sensor and actuator material systems can be developed, which, when integrated into mechanical components, enable perturbation energies to be controlled.



By means of adaptronics, structures whose properties can adapt to varying conditions are created. These active structures are key to meeting demands for better products with regard to performance, service life, lightweight design and function. For instance, load control or structural health monitoring can enhance safety, improved lightweight design optimizes comfort features and precision, mechanical system functions are simplified.

Picture 1:
Schematic representation of an adaptronic system, shown with the example of a device mounting system.
black: passive components
red: active components

AREAS OF SCIENCE

For the development of adaptronic structure systems, the following fields are of particular relevance:

- Intelligent material systems
- Design and development
- System integration and functional verification
- Technical reliability

Accordingly, the Fraunhofer Adaptronics Alliance works continuously on R&D projects aiming at optimizing structures and increasing the know-how required to develop application-specific problem solutions.

An important aspect is the development of new, intelligent material systems, in order to enable the use of components with improved coupled, e. g. electro-, magneto- and thermomechanical functional properties. Moreover, the relevant system components such as actuators, sensors, electronic components and software are further developed, with a view to increasing reliability and reducing costs. New methods and tools for designing and manufacturing adaptive components and systems are developed to allow the handling of small to medium-sized production lots. Finding ways that allow cost-efficient production of robust, adaptive systems involves production engineering, design rules, system analysis and system simulation. ‚System integration' is the keyword for combining and implementing these areas. Operational reliability must be determined and ensured under all relevant conditions.

Picture 2: The Spokesman of the Alliance: Prof. Dr. Holger Hanselka.
Picture 3: The Managing Director: Dr. Tobias Melz.

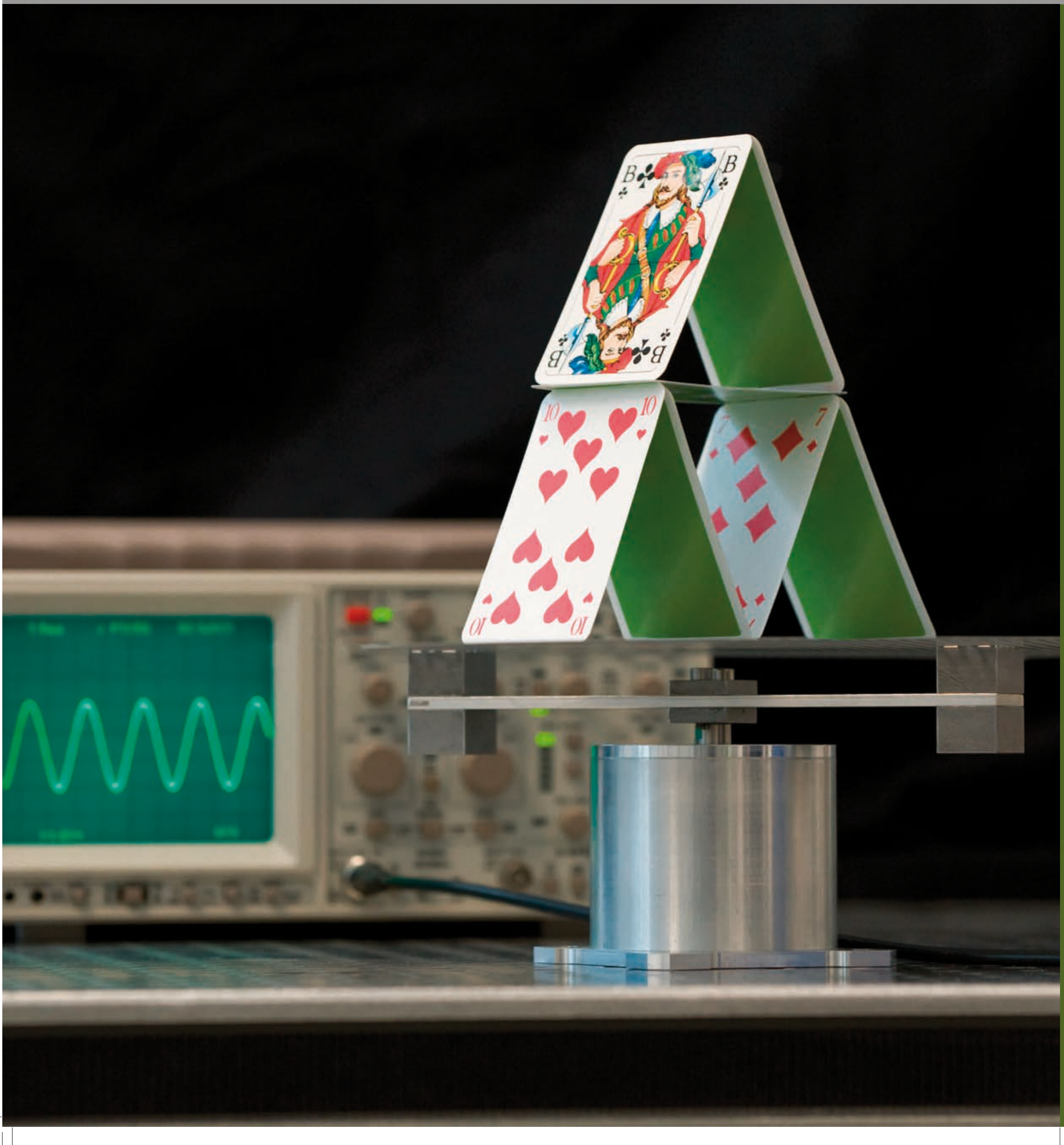
FRAUNHOFER ADAPTRONICS ALLIANCE

With a view to Fraunhofer's application-oriented research mission, 11 institutes, engaged in complementary subject areas, cooperate within the Fraunhofer Adaptronics Alliance.

Depending on the application, the partners of this Alliance work together in scientific as well as industrial research cooperations, thus bringing about interdisciplinary-based solutions from a single source. The partners' expertise covers the following areas:

- Materials and components
- Numerical and experimental simulation
- Electronics and control engineering
- Production and processing
- Systems, evaluation and application

ACTIVE VIBRATION CONTROL



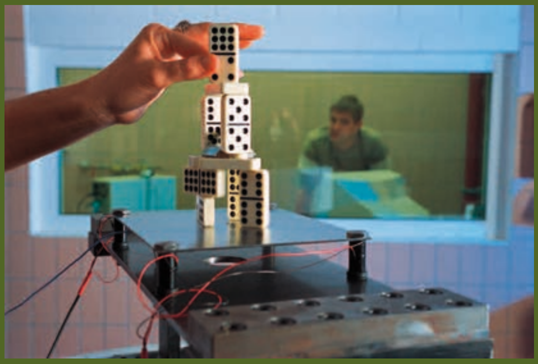
Working principle:

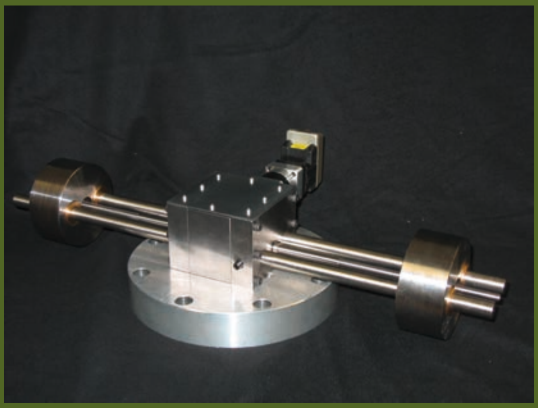
Usually, active vibration control aims at reducing vibrations. In many cases, the approach to solution is based on active mounting of the source of disturbance (e.g. a motor) or of the disturbed system (e. g. a sensor unit). Alternatively, spring-mass absorber systems such as adaptive absorbers or inertial mass actuators mounted to the structure may help reduce disturbing, often damaging vibrations. This is called Active Vibration Control (AVC).

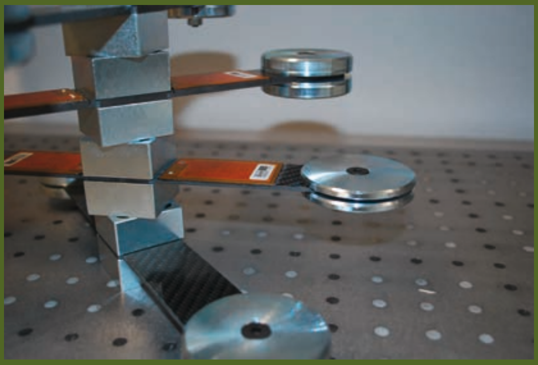
Application example: Reducing vibrations with the help of adaptive absorbers

Lightweight structures are prone to vibration. One approach to solving this problem is the use of adaptive absorbers whose resonance frequency during operation automatically follows the exciter frequency, thus providing for optimum compensation at any given time. Adjustment of the resonance frequency of a spring-mass system is in most cases effected by changing the spring stiffness. Another possible option is changing the mass. However, usually this involves costs and complexities and is therefore only interesting for very large absorber systems, e. g. for ships or large buildings.

Adaptive absorbers may be used in applications involving varying speeds, the start-up of plants, changing loads during operation and variable natural frequencies due to changing temperatures and non-linear material behavior. Higher speeds and smoother operation can be achieved. Adaptive absorbers are suitable for applications in a number of fields of mechanical engineering such as automotive technology, aviation or plant engineering.







Picture 1: Active vibration decoupling with piezoceramic transducers.
Picture 2: Motor-driven adaptive absorber for low and medium frequencies and low to medium loads.
Picture 3: Adaptive absorbers with piezoceramic actuators for higher frequencies and low to medium loads.

ACTIVE NOISE CONTROL

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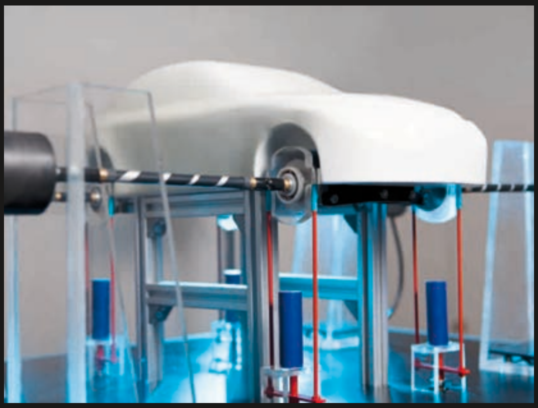
Working principle:

Analogously to AVC, adaptronic approaches can also be applied to control sound radiation from structural components. Adaptive Structural Acoustic Control (ASAC), as opposed to alternative active approaches for noise reduction, aims at controlling disturbance propagation even within the structural components in order to prevent sound radiation at its roots.

Application example:
Active engine mounts for reducing structural vibration and structure-borne sound transmission

To efficiently reduce noise and vibrations on board ships, active mounts for vibration isolation have been developed. For this purpose, piezoceramic transducers whose sensor functions are linked to each other via an electronic controller, are applied. The vibrations induced by the engine are measured and phase-, frequency- and amplitude-adapted forces are applied to the structure. Thus, mechanical properties such as the damping effect or stiffness of the engine mounts can be actively influenced. This solution is appropriate for a large range of applications and may be integrated directly into conventional mounts.

The active bearing concept designed for this purpose enables intervention by means of actuators, in frequency ranges from 30 to 350 Hz, in which passive conventional elastomer bearings are not effective or at least insufficient. This active engine mount acts directly in the line of force of the mounts, thus reducing the transmission markedly better than passive solutions. This is what makes this concept so very different from other approaches in which an opposite vibration is generated by means of electrodynamic compensators which do not act in the line of force of the mounts. In ship building and other industries such as automotive engineering, rail vehicle or aircraft construction, vibration and noise-reduced engine mounts are therefore of particular significance, both with regard to their economic potential and their technological superiority.



Picture 1: Experiment on sound propagation in automobiles.
Picture 2: Model of an experimental test rig for the development of active systems in automotive engineering.
Picture 3: Active engine mounting is tested in the North Sea.

ACTIVE SHAPE CONTROL / SPECIAL ACTUATORS

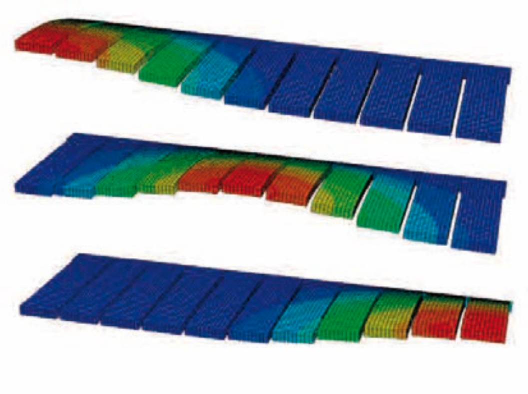
Working principle:

Integrating suitable multifunctional materials into structural components (e. g. reflectors) enables active control of their shape or their properties. In contrast to conventional approaches, this allows continuous control of the elastic shape while the design can be kept compact and lightweight; in addition, novel actuator concepts for optimum enhancement of functionality may be implemented.

Application example:
SMA actuators as a basis for a sensorless drive and control concept for exoprostheses

As a result of significantly improved material properties, the use of thermal shape memory alloy (SMA) actuators is increasingly in the focus of application-oriented research. Machine tools and automotive engineering are not the only fields of application for these actuators: Shape memory materials also open up new horizons in medical technology. Currently, thermal SMAs are investigated as to their suitability for being used as actuators for exoprostheses. In this area, the primary aim is to develop a sensorless drive and control system to supplement existing drive systems of externally powered prostheses.

The actuator wires are tensioned in the forearm of the gripping system and, via artificial tendons, transmit their tensile force to the fingers. Thus, the actuators mimic real muscles. To illustrate the working principle, the joint structure has been limited to a total of 9 swivel joints in a current test component (see picture 2). The result of this development is a gripping mechanism based on a „self-sensing actuator", which offers various approaches to supplement existing actuating systems for exoprotheses and ortheses.



Picture 1: FEM simulation of the pump function of a micropump with PZT-CFRP bending arrays.
Picture 2: Pincer grip with the help of an SMS self-sensing actuator.
Picture 3: MRF coupling for automotive application in the field of electromobility.

STRUCTURAL HEALTH MONITORING

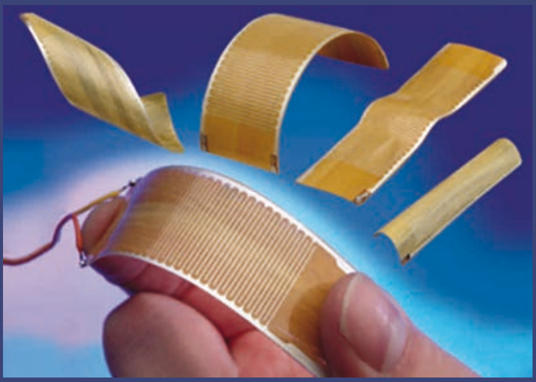
Working principle:

Adaptronic approaches enable the controlled introduction of vibrations into structures. Using appropriate signal processing, resulting reactions in these structures may be evaluated with regard to mechanical stress or damage characteristics. Thus, structural components can be monitored during operation, and maintenance measures may be initiated when the need arises. Alternatively, the described AVC or special-actuator-based approaches may be applied to minimize mechanical stress to which structural components are exposed, thus increasing service life and operation reliability.

Application example: Structural Health Monitoring for monitoring the behavior of structural components

Currently, scientists of the Fraunhofer Adaptronics Alliance are investigating the possibilities of using natural factors such as wind or water for automated vibration analysis. Lengthy, costly hammer tests might be rendered superfluous, at least in part, by using this so-called „Output Only Modal Analysis" (OMA). Monitoring the structural behavior is not only important for bridges, but also for ships, wind turbine systems or aircrafts. In the latter, electrodynamic exciters mounted under the wings are commonly used as defect indicators. OMA, which supplements existing test methods, does not rely on artificial excitation (such as hammers or shakers), but makes use of natural sources of excitation which are available in the environment.

For instance, to monitor a wind turbine structure, excitation by the wind itself may be used. For this purpose, two acceleration sensors are attached in a test set-up, and the recorded vibration data is processed by two integrated signal processing systems. One of these conditions the signals and compresses the data, whereas the second one is used for further evaluation and determination of structural characteristics (in this case the resonance frequencies). If the resonance frequencies change during operation, this may be an indicator of structure damage.



Picture 1: Aluminium pedal crank with integrated piezoceramic transducers to determine power loss and effective power during cycling.

Picture 2: Piezoceramic transducers for vibration excitation.

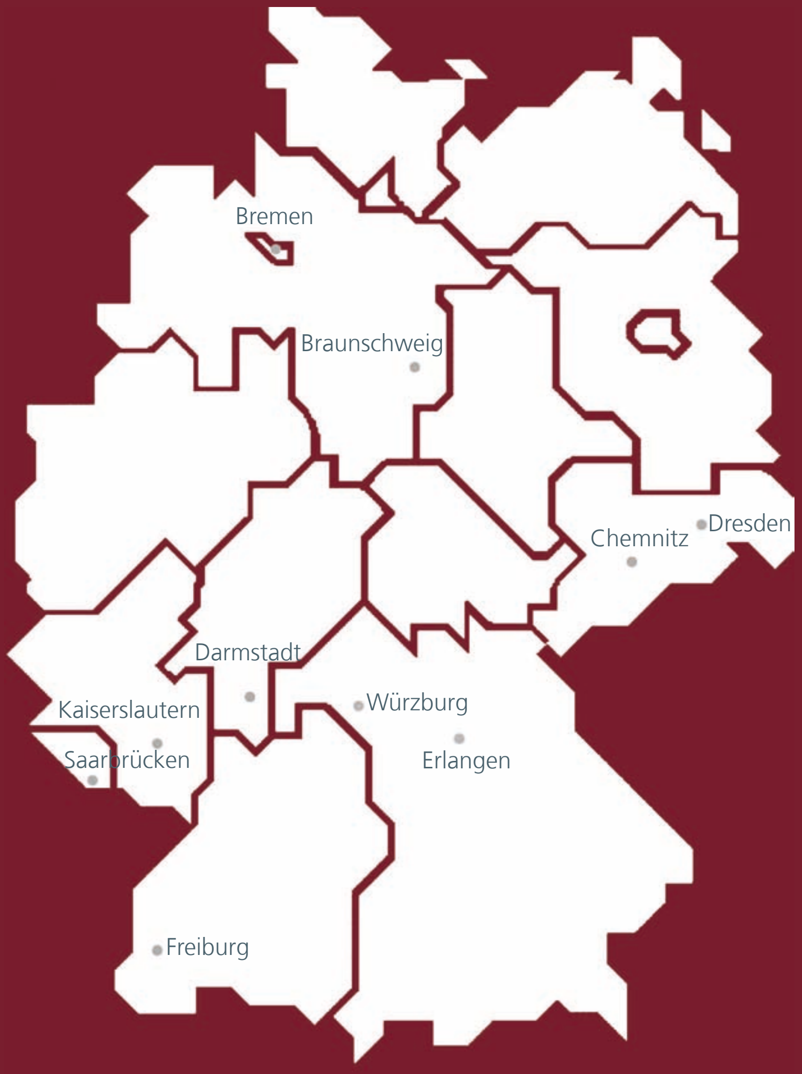
Picture 3: Plane model with integrated SHM sensors.

ADAPTRONICS – CHANGING TECHNOLOGY

Member Institutes

Fraunhofer Institute for

- Structural Durability and System Reliability LBF, Darmstadt
- Manufacturing Technology and Advanced Materials IFAM, Bremen
- Integrated Circuits IIS, Erlangen
- Ceramic Technologies and Systems IKTS, Dresden
- High-Speed Dynamics, Ernst-Mach Institute EMI, Freiburg
- Surface Engineering and Thin Films IST, Braunschweig
- Silicate Research ISC, Würzburg
- Industrial Mathematics ITWM, Kaiserslautern
- Mechanics of Materials IWM, Freiburg
- Machine Tools and Forming Technology IWU, Dresden
- Non-Destructive Testing IZFP, Saarbrücken



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