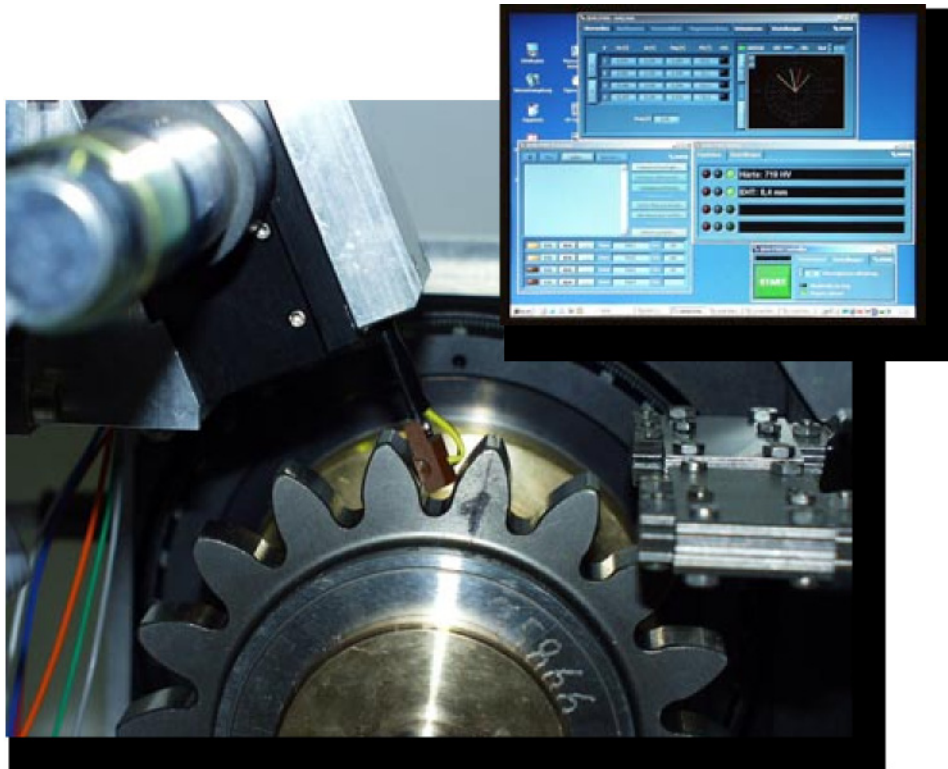


3MA-II



Hardness
Case Depth
Yield Strength
Tensile Strength

Situation

To achieve the required fitness for use, parts and components used in mechanical engineering and aviation, automotive and utility industry are subject to thermal and mechanical treatment. The tribological and mechanical properties of the surface and subsurface area are crucial for the function and durability of highly stressed components. The systematic maintenance of these boundary area characteristics requires the application of adequate measurement techniques. Metallurgical analysis, residual stress state measurements with X-ray diffraction and conventional indentation hardness testing methods are used to achieve this objective. Inherent to these methods is the slow testing process and the destructive nature of conventional test procedures. Therefore, these methods are inadequate for in situ inspection of the surface areas during, or shortly after, a certain manufacturing stage within the processing chain.

Solution

The 3MA (**M**icro-magnetic **M**ulti-parameter **M**icrostructure and **S**tress **A**nalysis) technique represents a contemporary measurement technique for the nondestructive characterization of surface and subsurface areas. Aside from permitting full automation, the technique can be integrated into various manufacturing processes. With its fast test performance, it typically yields the ability of 100% test coverage for most applications. The technique allows fast and concurrent evaluation of several relevant quality characteristics of the surface and subsurface areas (0–8 mm depth). This is achieved by combining complimentary information from different microstructure and stress sensitive testing statistics. The only prerequisite is ferromagnetic material, i.e. magnetizable steel, and a preceding calibration, for which an approximation function is retrieved via multiple regression analysis or nearest neighboring pattern recognition that correlates the desired quality characteristics (target values) to the 3MA measurement parameters (test statistics).

Equipment

The 3MA-II system combines four different micro-magnetic measurement procedures, Barkhausen Noise (BN), incremental permeability (μ'), harmonic analysis of the tangential magnetic field strength (Ht) and multi-frequency eddy current analysis. Several test statistics are evaluated for each procedure, adding to a total of 41 micro-magnetic test statistics. The advantages of combining test statistics in a multi-parameter procedure are manifold, especially when the target values (e.g. hardness, case depth) and the disturbance variables (temperature, residual stress, etc.) are subject to concurrent variations. The individual micro-magnetic test statistics exhibit diversified sensitivity significances towards the target values and test statistics; thus facilitating the elimination or at least the reduction of the disturbance variables influence. Every implemented 3MA micro-magnetic procedure is distinguished by a particular range of analysis depths; therefore, the synthesis of the procedures enables the analysis of depth dependent gradients of microstructure, material properties and residual stresses.

All test statistics are acquired by time multiplexing during a single data acquisition process at up to 40 measurements per second. The 3MA-II system calculates a reference value for every calibrated target value, which are displayed in real-time. Potential target values can be a variety of material properties; their specifications depend on the microstructure and the residual stress profile, for example:

- Hardness
- Case depth
- Residual stress
- Characteristics of tensile testing (tensile strength, yield strength, ultimate strain, etc.)

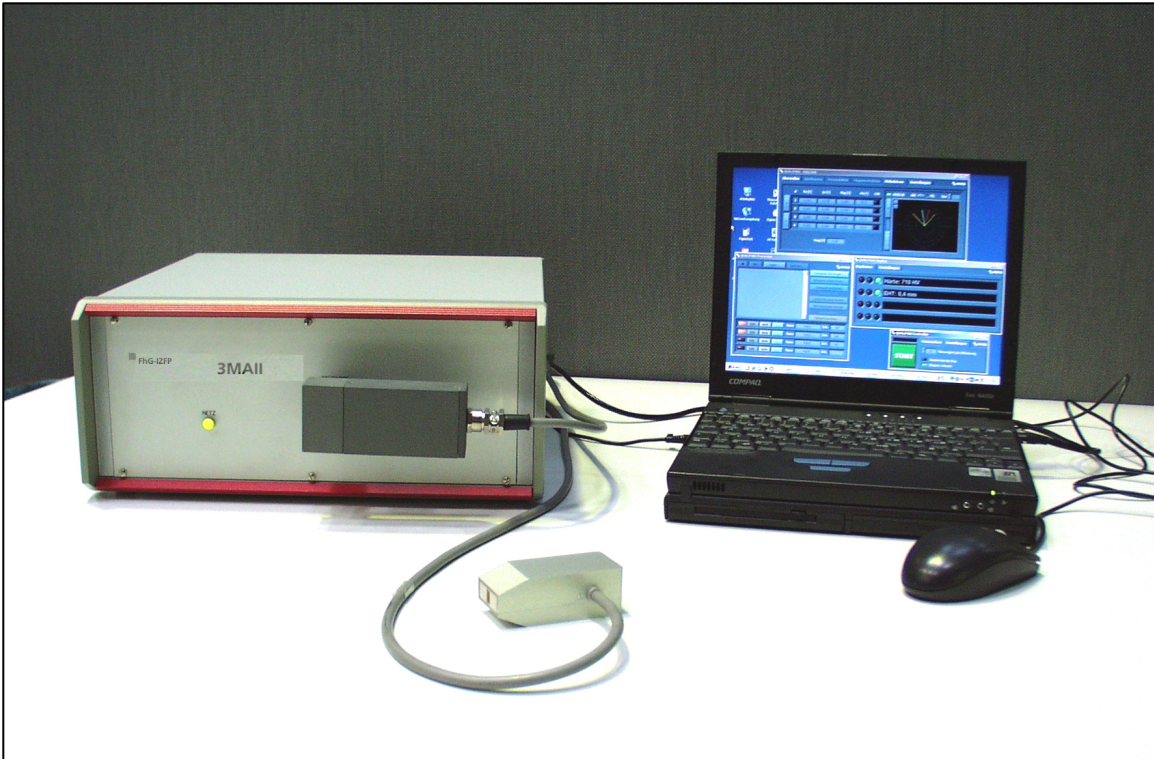
The most important components of the 3MA-II system are the sensor and the hardware front-end with an integrated controller. The sensor, consisting of a magnetization unit and a transmitter/receiver unit, can be adapted and customized to almost any component geometry and particular user requirements.

In order to enable easy integration into existing data supply and process control systems, the hardware front-end can be connected to any computer (Industrial PC, Desktop PC, Notebook, and Network Server) via Ethernet. The front-end is constructed in modules to accommodate low effort replacement and installation of defective, outdated or upgrade components.

Analog to the hardware, control and evaluation of the software is conceived modularly. The Modular Measurement System (MMS) distinguishes itself by user-friendly ease of operation. Additional software modules assure simple, highly automated instrument adjustment and calibration. Further custom-designed modules are available for a variety of applications.

Advantages

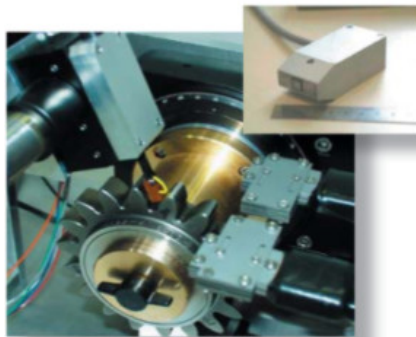
- Fast nondestructive testing
- Continuous monitoring and documentation of quality characteristics
- Substitutes destructive testing methods
- Cost-effective production due to reduced costs for testing and consequential costs (caused by nonconforming parts)
- Complete and comprehensive process monitoring by integration into the manufacturing process
- Customization according to special requirements (sensors, software)



3MA-II System - Front-end & Sensor (left), PC for Data Processing, evaluation & documentation (right)

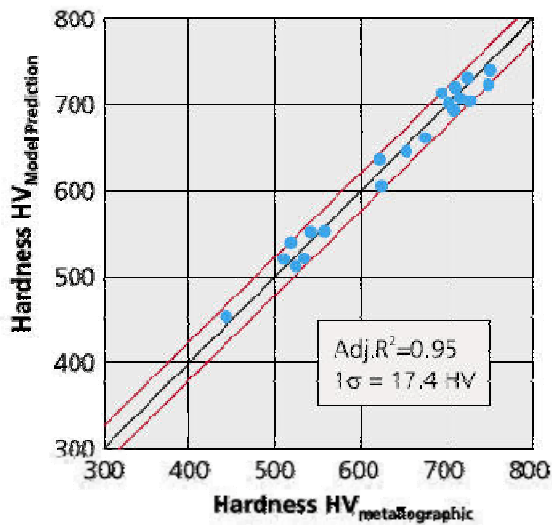
Applications

- Locally resolved measurement of hardness, case depth and residual stress state after hardening
- Detection and characterization of machining flaws
- Continuous monitoring of tensile strength, yield strength, etc. in steel strips and plates
- 100% verification and documentation of steel quality
- Hardness and case depth of induction-, case-, laser- and nitriding- hardening
- Reduced setup and change-overtime
- Deep drawing properties and residual stress states of steel sheets
- Incoming part inspection for sheet metal forming
- Determination of residual stress states of assembled components
- Assembly-inspection, compound strength
- Early detection of thermal deterioration, neutron embrittlement, fatigue, creep damage.
- Recurring inspection of safety relevant components for in-service inspections.

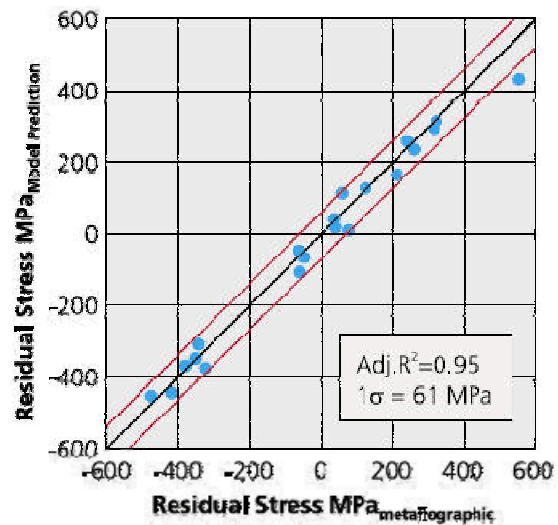


Standard Sensor
for Manual Testing

Dual-Sensor for Automated Testing
(Gear Wheels)



3MA-II Hardness Testing
Calibration on Diamond Penetrator
Hardness (DPH 0.05)



3MA-II Residual Stress Testing
Calibration by X-ray Diffraction