

# Eddy current testing

for safe components



proof.

## The Company

**FOERSTER is a global technology leader for non-destructive testing of metallic materials. One of the “Hidden Champion” companies, FOERSTER works closely with its worldwide customers through its extensive network of ten subsidiaries and qualified representatives in more than 60 countries.**

### **FOERSTER Component Testing (CT)**

Division CT (Component Testing) develops testing instruments as well as customized and fully-automated complete systems for non-destructive quality control of metallic components in the fields of automobile manufacturing and supply.

These devices use the eddy current method to detect and document with maximum sensitivity and repeatability such surface defects as cracks and pores. Contactless operation makes this method ideal for use even on sensitive surfaces.

Another field of application is the testing of material properties to prevent mix-ups and for early detection of incorrect tempering conditions. These magneto-inductive systems are particularly suited for ascertaining surface hardness and hardening depth on diverse component geometries.

The CT testing instruments and systems have been developed specifically to meet the needs of the automotive industry and its first- and second-tier component suppliers. Companies worldwide rely on the superior testing capabilities provided by FOERSTER inspection technologies to verify the integrity of components critical to safety or long service life, such as wheel hubs, brake discs, camshafts, drive shafts and valves.



## Quality control in the automotive industry



**Ever-increasing quality expectations in the automotive industry are a huge challenge for suppliers. It is simply no longer possible to meet these requirements without continuous quality control built into the production lines of each component.**

### **FOERSTER testing systems**

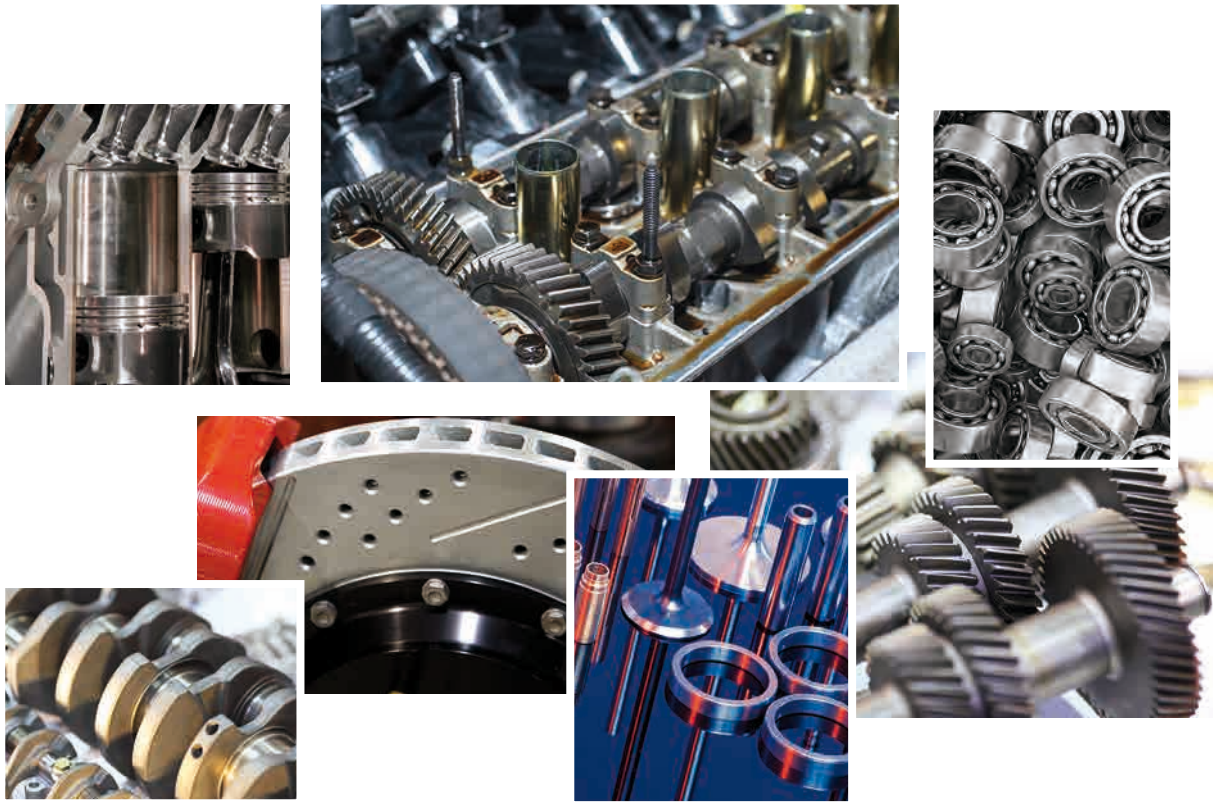
Developed specifically for monitoring the quality of components, test equipment from FOERSTER is used wherever utterly reliable yet cost-effective analysis is required. Qualified application and sales engineers work closely with the users to determine the best possible configuration for the testing system, from both the technical and the financial points of view.

### **Economical testing of automotive components**

The highly advanced manufacturing technologies used in today's automobile engineering require manufacturers and suppliers to rely on fully automated quality control for testing and monitoring various processes. The reasons for this include:

- Ever-increasing requirements for safety and efficiency
- Directives of product liability laws
- Documentation obligations
- Quality management system requirements for certification

## Quality control of components



**Continuous developments in the automotive industry, for example to extract ever-greater performance out of ever-smaller and lighter engines, place steep demands on the material. The individual components must withstand such stresses as high temperatures or friction; even the smallest cracks in the material or the wrong material properties can lead to total failure. Only absolutely reliable crack and structure testing of the respective components can guarantee their proper functionality.**

### **Variety of applications**

The manufacture of a vehicle involves a multitude of components. Each and every component plays an important, often safety-related, role – whether in the transmission or engine, to direct the power to the street, or in the braking system, to bring it all back to a safe stop.

This results in a wide range of applications, for which FOERSTER has developed specialized test systems.

These include:

- Valves and valve stems
- Valve seat rings and seats
- Camshafts
- Cylinder liners
- Transmission and drive shafts
- Gear racks
- Ball pins
- Wheel hub
- Break discs
- Transmission bell housings
- Axle pivots
- Piston rods/pins
- Bearings

## Non-destructive eddy current testing

An acute awareness of quality – combined with the issues of product liability – increasingly leads to a 100% inspection of the components involved. A non-destructive testing method is required to carry this out quickly, reliably and economically.

### The eddy current technology

The eddy current technology as per DIN EN ISO 15549 is a non-destructive and contactless method for testing materials. It detects material discontinuities and imperfections such as cracks, laminations, pores or cavities on the material surface. It also makes it possible to check material properties in order to identify faults such as material mix-ups or different tempering conditions.

Some of the typical sorting criteria are alloy proportions, surface hardness, hardening depth, strength and microstructure characteristics. The eddy current technology needs no physical contact and is therefore non-destructive. Additional media, such as coupling liquids, are also unnecessary. Even parts with delicate surfaces can be tested easily.

### Crack detection and microstructure testing

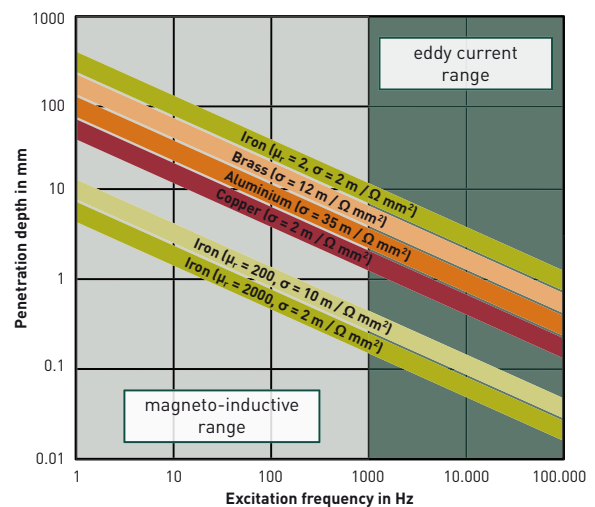
Due to its wide frequency range, the eddy current method can be used for a variety of test purposes. The low-frequency magnetic induction testing allows for greater penetration depth, thus providing informa-

tion about the tempering of the test sample. With this kind of material and/or structure testing, it is possible to rule out the use of wrong materials or determine hardening depths.

With high-frequency eddy current testing, it is also possible to identify surface fissures – so-called discontinuities; this is also known as “crack detection”.

### Advantages of the eddy current method

- High testing speed
- High test throughput
- Easy to automate
- 100% testing
- Objective results evaluation
- High reproducibility
- Documentation and recording of test results
- No contamination by coupling liquids



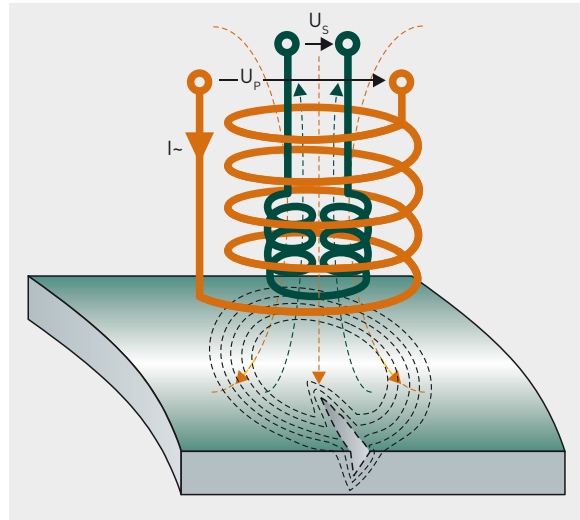
Areas of application for the eddy current method

## Crack detection

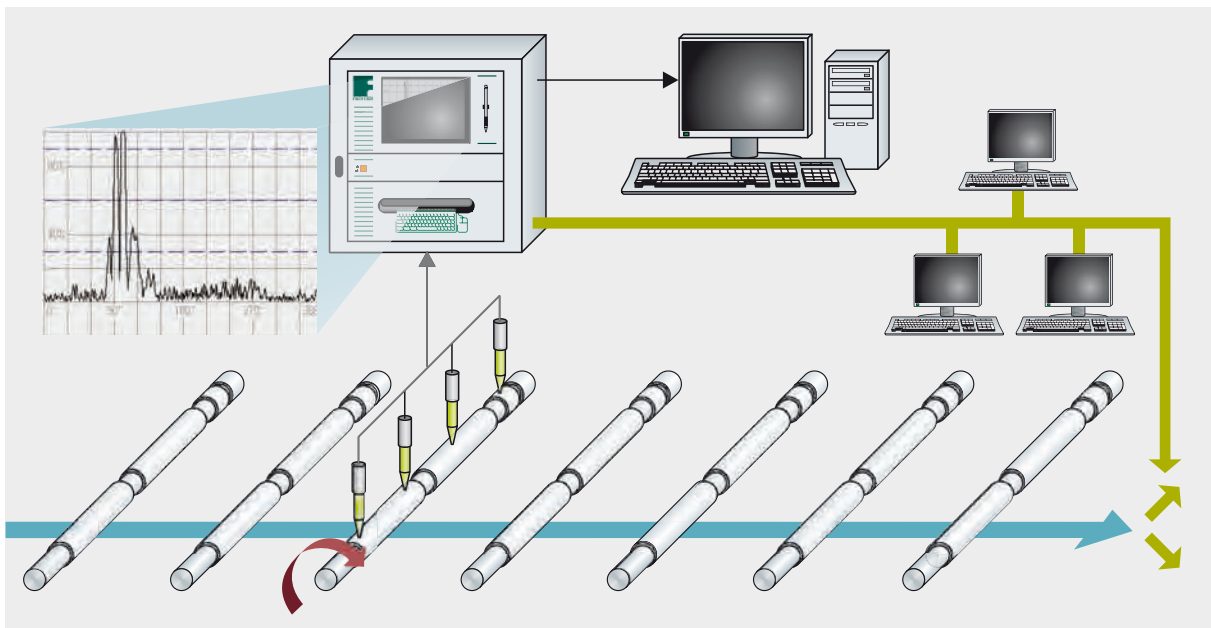
### Detecting cracks in the material

In crack detection, the surface of the part to be tested is scanned – without physical contact – by one or more eddy current probes. For this purpose, the test item is rotated by a specially-adapted mechanism and then scanned by a stationary probe. Alternatively, a rotating probe scans the stationary test item.

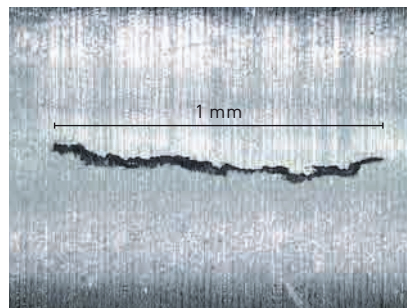
The system can incorporate either one test track along the sample's circumference with a single probe or several test tracks with probes arranged in parallel. Alternatively, the surface to be tested can be scanned with a probe that tracks its contour. The choice of probe depends on the geometry of the component, the cycle time and the defect specification.



*This illustration shows how a crack, for example, affects the characteristics of the eddy current in a conductive metal*



*Contactless eddy current crack detection can also be integrated into more complex manufacturing sequences. The illustration shows how the components are examined during automated 100% testing, while the test results are documented online and the data processed for documentation. Furthermore, the defective parts are sorted out*

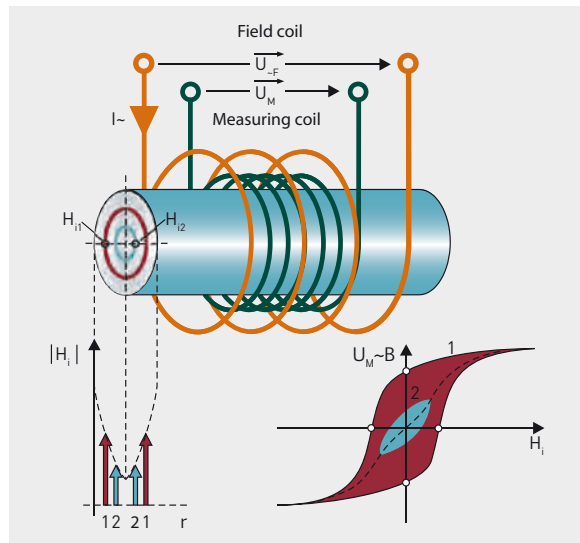


*Natural cracks in turned surfaces*

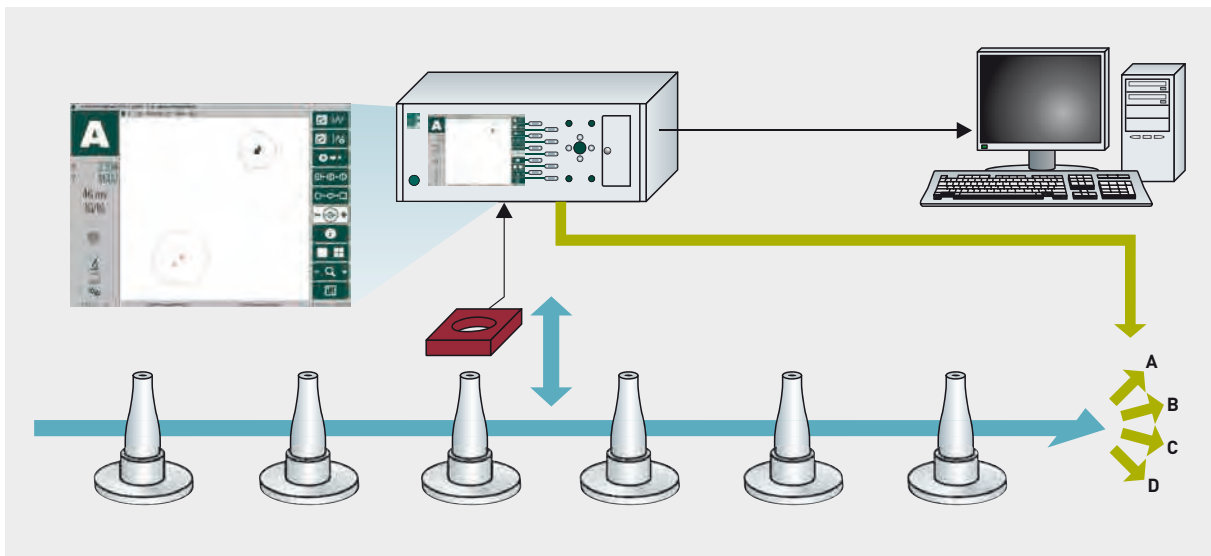
## Material and microstructure testing

### Checking materials for their properties

For testing of material properties, the specimens are passed through an encircling testing coil. For particular applications, e.g. local checks for surface hardness or hardening depth, specimen-specific sensor systems are used. The voltage detected by the individual sensors results from the magnetic and electric properties of the specimen. The exact voltage is displayed as a measuring point. During calibration, a sorting limit is automatically created through the statistical evaluation of multiple measured values. In subsequent serial testing, all further measuring points are compared against the specified tolerance limits. The parts are sorted according to the respective test results.



Magneto-inductive testing determines the significant material properties from the electrical and magnetic characteristics of the ferromagnetic components

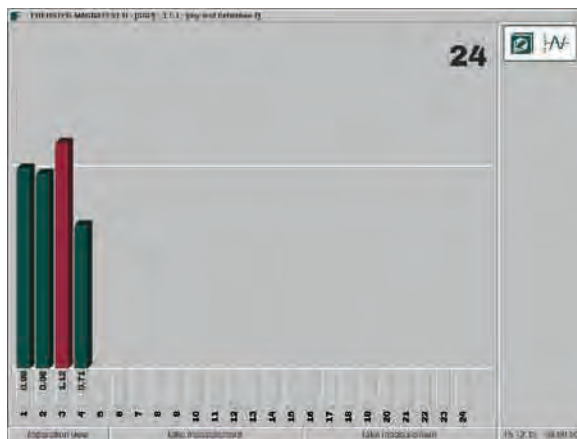


In modern production lines, magneto-inductive testing for material properties is completely automated

## Multi-frequency testing and harmonic analysis

### Multi-frequency testing

The combination of multiple frequencies and magnetization field intensities makes it possible to evaluate different material properties at the same time and/or to selectively suppress disturbance variables. Serial multi-frequency testing works with several different testing frequencies. The individual pieces of test information are determined consecutively in a single testing procedure with the defined frequency settings – and entirely controlled by the automated testing system. As the tests take place in series, the overall testing time is determined by the number of set frequencies.

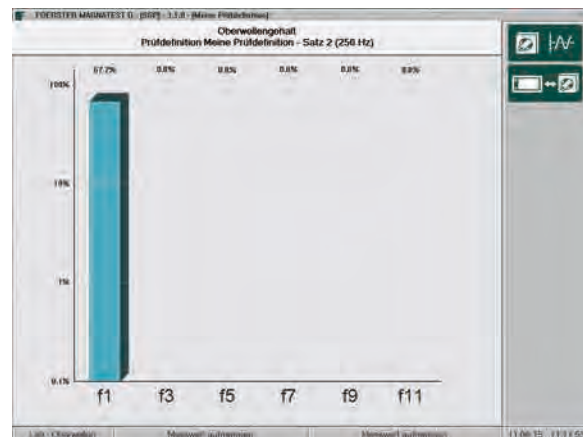


With multi-frequency testing, the results of up to 24 individual frequencies, with their corresponding separation indices, are shown in an overview

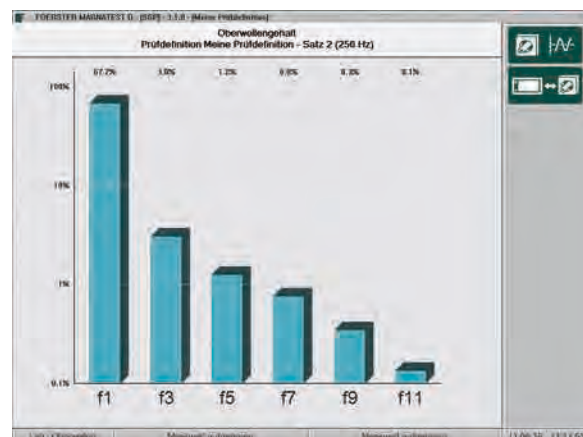
### Harmonic analysis

The harmonic analysis method is extremely beneficial when good repeatability is required despite interferences such as variable specimen temperature or misalignment of the piece within the test coil. In contrast to the standard single- or multi-frequency eddy current testing, this method guarantees consistent test results: even a batch change will not necessitate recalibration.

The strong, linear power amplifier of the MAGNATEST devices provides the basis for harmonic analysis. In high-energy modus, the components to be tested inside the MAGNATEST coil are penetrated by a strong alternating magnetic field; the resulting magnetization of ferromagnetic parts produces a so-called hysteresis loop, which is a very sensitive indicator of inconsistencies in material structure or grain size. Therefore, using high-energy excitation of the magnetic field, it is possible to evaluate the hysteresis loop of the sample, which the MAGNATEST device interprets as harmonics (the odd multiples of the transmission frequency). However, the principle of harmonic analysis with many receiving frequencies (one for each transmission frequency) must be distinguished from simple multi-frequency testing with several transmission frequencies.



Spectrum of the received signal with evaluation of the fundamental wave or multi-frequency testing



Spectrum of the received signal with high-energy harmonic analysis

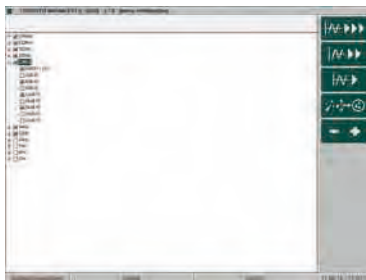


## Professional software assistance

### Application assistant reduces operator effort

The capability to separate out substandard parts with magneto-inductive testing depends on the test parameters, especially the test frequency and the magnetic field strength. The application assistant automatically determines the optimum settings for positive material identification based on the preselected parameters, significantly reducing the amount of work for the user.

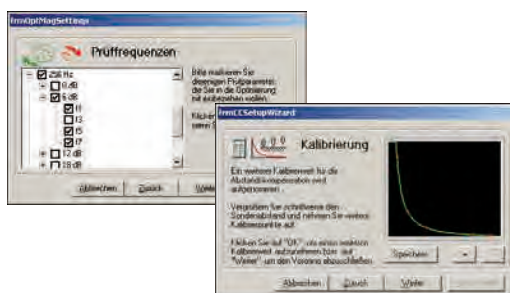
- Step-by-step operator guidance through the optimization process
- Calculation of the separation after collecting at least five good parts
- Display of the optimum test settings after testing the part to be separated
- The determined test parameters are activated by the operator for routine testing



Display of the possible parameter combinations for test systems MAGNATEST D and MAGNATEST ECM Compact Edition

Parameter [Hz]	Disturbance	Measurement L	Signal L	Index	Measurement H	Disturbance H	Signal H	Index H
100%	500	F1	8.82	9.75	12.85	19.3	21.1	21.1
200%	500	F1	8.81	8.68	19.11	49.38	51.1	51.1
300%	500	F1	7.74	8.13	18.18	46.3	48.1	48.1
400%	500	F1	7.79	8.08	18.08	46.22	48.1	48.1
500%	500	F1	5.15	5.92	8.22	38.77	40.1	40.1
100%	1000	F1	5.17	5.28	8.91	37.1	38.1	38.1
200%	1000	F1	8.84	8.38	18.16	37.1	38.1	38.1
300%	1000	F1	8.14	8.14	18.16	37.1	38.1	38.1
400%	1000	F1	8.14	8.38	18.16	37.1	38.1	38.1
500%	1000	F1	8.14	8.38	18.16	37.1	38.1	38.1
100%	1500	F1	4.82	5.18	8.22	18.22	19.1	19.1
200%	1500	F1	8.11	8.38	18.16	37.1	38.1	38.1
300%	1500	F1	8.11	8.38	18.16	37.1	38.1	38.1
400%	1500	F1	8.11	8.38	18.16	37.1	38.1	38.1
500%	1500	F1	8.11	8.38	18.16	37.1	38.1	38.1

If two separation conditions are possible, the set of parameters with the best separation (highest separation index) is already marked. The separation capability depends on the type of tolerance field, so the value is displayed for all possible test categories

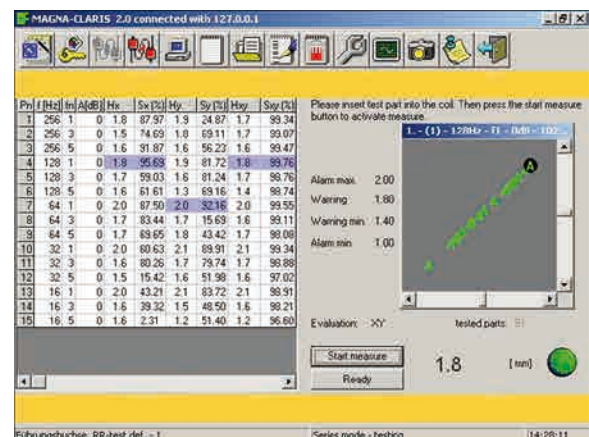


The assistant function is also available with the test system STATOGRAPH ECM Compact Edition. Beside dynamic determination of the best test settings, it is also possible to use a menu-guided assistant for optimization of the clearance compensation

### MagnaClaris

The results of magneto-inductive testing depend on the electrical and magnetic properties of the test piece. This factor is closely linked to the technological properties of the material. The nearly linear correlation between the test data from MAGNATEST D and the technological properties of the test pieces permits (after calibration) the determination of a technological value based on a linear regression calculation. Besides the two-dimensional eddy current value, the conventionally determined technological value is also stored.

In a next step, the software calculates the regression line. The quality measure of this correlation is defined as a correlation factor with either a numerical value or a percentage: the higher the value, the more precise the parameter. This means that the technological value of unknown parts can be calculated with the eddy current values. The field of application must be verified in any case.



Test result display with MagnaClaris

## Crack detection with STATOGRAPH®



### STATOGRAPH® ECM

Depending on the testing situation and the sample, the instruments of the STATOGRAPH series are ideal for professional crack detection. The STATOGRAPH ECM is an economical yet fully line-compatible base system featuring modern microcontroller technology with a PC interface; it is suited for straightforward, standard applications. Testing begins with the test statement "good" or "bad"; optionally, the system can also be expanded via an external PC with the eddyAssist operating and visualization software. Furthermore, the STATOGRAPH ECM can be extended into a multi-channel inspection system.



### STATOGRAPH® ECM CE

In the STATOGRAPH ECM CE (Compact Edition), the test module and the eddyAssist operating software are merged into a compact unit that nevertheless offers full functionality. With minimal design effort, this single-channel test system can be retrofitted easily into existing plants.



### STATOGRAPH® DS

The processor-controlled eddy current system STATOGRAPH DS for fully automated single- and multi-channel crack detection is suitable for simultaneous testing of different areas. The instrument produces detailed documentation of the test results, and an interface to a higher-level quality management system is available as well. Further features include digital signal processing for automatic, high-resolution, multi-channel online error/crack detection and individual adjustment of the separate test channels, error compensation and group sorting. A WINDOWS® based, menu-driven operating system with an intuitive application wizard facilitates running the device, entering settings and carrying out automated reconciliation procedures.



### STATOGRAPH® ECM Multi-channel

Built into an industry-standard 19" equipment cabinet, the variable multi-channel STATOGRAPH ECM can be customized to user specifications. Its modular structure allows for expandability, for example for magneto-inductive testing. The system components are optimally protected from dust and dirt. In addition, the standard system comes equipped with a closed-circuit cooling device.

## Probes and sensor systems for crack detection



### Probes for crack detection

A comprehensive range of standard eddy current probes – both fixed and rotary – is available for a huge variety of testing jobs. The right probes make it possible to design inexpensive solutions for typical testing functions.



### Special sensors

If a task requires specialized solutions, FOERSTER designs and custom-manufactures sensors for the individual purpose, whether that entails adapting existing standard sensors or completely rebuilding the sensor geometry. For example, probe elements can be produced with angled heads, as well as sensors for fitting into extremely narrow cavities or eccentric components like camshafts.



### Flexible probes

A special type of sensor is the so-called flex-probe. When combined with variable radius holders they can be easily adapted to the differing geometries of different test pieces. Flex-probes are especially useful for the testing of curved parts. Due to their wide track, surfaces can be scanned quickly.



### Rotating sensor systems

If the task requires it, testing can be carried out with rotating sensors and a stationary specimen. Various rotating heads and rotary probes are available for this purpose. In this case, the testing unit consists of a driver and a rotary probe tip. Testing with rotating sensor systems allows for high throughput while keeping the handling effort low.



## Material and microstructure testing with MAGNATEST®



### MAGNATEST® ECM

Depending on the test situation and the sample, the MAGNATEST equipment family offers excellent solutions for magneto-inductive material and microstructure testing of metallic components. The line-suitable and compact module, MAGNATEST ECM, is ideal for single-frequency testing with group analysis and is used for straightforward standard applications, such as hardness testing or material sorting control. Its PC interface allows optional expansion with the eddyAssist operating and visualization software.



### MAGNATEST® ECM CE

In the MAGNATEST ECM CE, the MAGNATEST ECM test module and the eddyAssist operating software are combined into a compact unit that is especially useful when visualization of the test results is essential. In addition, because the class type is configurable by the user, the impedance plane and/or the gap between the good and the bad test samples can be viewed, evaluated and optimized. Depending on the inspection task, both MAGNATEST ECM and MAGNATEST ECM CE can be extended with an external power amplifier.



### MAGNATEST® D

The processor-controlled, compact MAGNATEST D is designed for fully automated magneto-inductive testing of material properties in single-coil absolute mode. In addition to the fundamental wave, the harmonic components of the test signal can also be utilized. Evaluation is carried out as group analysis in up to six sorting categories, where the shape and size of the tolerance ranges can be individually adjusted. When testing in serial mode, a maximum of 24 stored and individually defined parameter sets can be used. The menu-guided FOERSTER setting assistant is integrated into the program structure. The MAGNATEST D is the world's most frequently used computer-assisted device for non-destructive testing in the automobile industry.



### MULTIPLEXER MAGNATEST® D

Using a multiplexer for electronic switchover into multi-coil operation, the MAGNATEST D can be connected with up to 16 probes and supplemented by one or more frequencies. Comprehensive documentation options for the test data include test sample statistics, histogram and data export. An interface for connecting to higher-level quality management systems enables networking and extensive statistics. A multiplexer also results in shorter cycle times and streamlined mechanics, even for multiple test zones on the sample, because the individual coils remain stationary throughout the procedure.

## Coils and probes for magneto-inductive testing

### Coils for testing of material properties

Based on the test arrangement, the sensors for testing material properties are designed either as coils or as probes. The various MAGNATEST devices are provided with a wide range of standard testing coils with round and rectangular cross-sections, as well as standard testing probes.



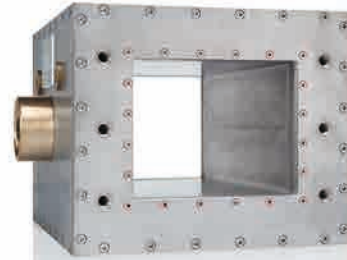
#### Coils

The size of the opening of feed-through coils depends on the items to be tested. The coils can be adapted as needed, depending on the shape and cross-section of the test item, thus making it simple to convert the test systems for other functions.



#### Probes

Wherever an enclosing coil cannot be used, specially-adapted probes are employed. This makes it possible to carry out testing in places that are difficult to access or to determine very local microstructure characteristics.



### Water-cooled coils

In order to examine the micro-structural properties of very hot samples, special water-cooled coils are used. Due to their robust design they are ideal for harsh environments, while the integrated cooling circuit significantly increases the life of the coil.



### Form-adapted probes

Probes with special shapes are mainly used for testing inside of a sample, for example to check the hardening depth. Compared to conventional coils, the optimized interaction volume produces better separation precision and higher reproducibility of the results.

## Automated testing

### Advantages of automated testing

In many cases, automating the testing is necessary to ensure smooth production processes. In addition to shorter cycle times, test reproducibility is improved by automation. As a system partner, FOERSTER provides its customers not only the test equipment but also the corresponding test concepts as a complete solution.

Typical applications for individual and automated testing concepts are the separation of bulk materials and the feeding of test pieces to the inspection station. This is followed by sorting and separation of the tested samples.

Depending on the type of testing, the sample handling or supply must be tailored to suit the test situation. For automated crack detection, the testing unit must be made to rotate, while in an automated microstructure test the parts must be moved through the coil.



*Fully automatic multi-channel crack detection system with automatic loading of the sample buffer*



*Fully automated crack detection system (Roto-Push) with conveyor*

## Consulting, Training and Service



### Custom Consulting

In order to ensure comprehensive and individual advice in response to special customer requests, application specialists conduct studies ranging from first investigations through to comprehensive feasibility studies. Using material provided by the customer, the best technical approach and the correct parameters are determined individually.

### Commissioning, service and maintenance

Expert professionals and specially trained service personnel are available for commissioning and maintenance of the systems. Even over the telephone, FOERSTER service engineers can conduct systematic troubleshooting and, if remote access is possible, a quick initial diagnosis can be made and first steps taken to resume operation as quickly as possible.

### Trainings and workshops

FOERSTER training courses focus on the practice-oriented application of FOERSTER test electronics, as well as the configuration of important parameters for adapting the systems to the test procedures and tasks at hand. The training content can be modified to suit an individual customer's needs and delivered on-site, directly at the test line.

### High-Quality Requirements for Service

When it comes to FOERSTER test instruments, customers can count on top quality. In order to meet these expectations, an experienced service team and highly skilled engineers are available for on-site service and maintenance projects and, as necessary, prompt and efficient assistance.

### Worldwide Reach

FOERSTER is a global company. A network of ten subsidiaries and qualified representatives in more than 60 countries guarantees close proximity to customers and rapid response.

## Worldwide Sales and Support Offices



### Headquarter

- Institut Dr. Foerster GmbH & Co. KG, Germany

### Subsidiaries

- Magnetische Pruefanlagen GmbH, Germany
- FOERSTER Tecom spol s.r.o., Czech Republic
- FOERSTER France SAS, France
- FOERSTER Italia S.r.l., Italy
- FOERSTER Russland AO, Russia
- FOERSTER U.K. Limited, United Kingdom
- FOERSTER (Shanghai) NDT Instruments Co., Ltd., China
- FOERSTER Japan Co., Ltd., Japan
- NDT Instruments Pte Ltd, Singapore
- FOERSTER Instruments Inc., USA

Furthermore, the FOERSTER Group is represented by qualified agents in more than 50 additional countries.

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