POWDER METAL

Process control for manufacturing and processing.

FOERSTER

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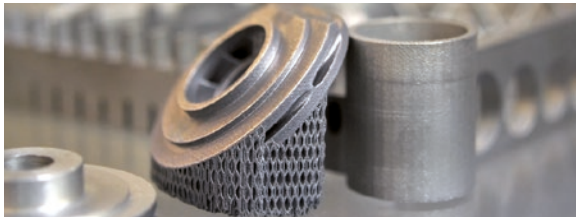
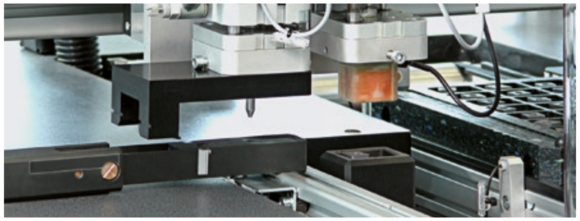


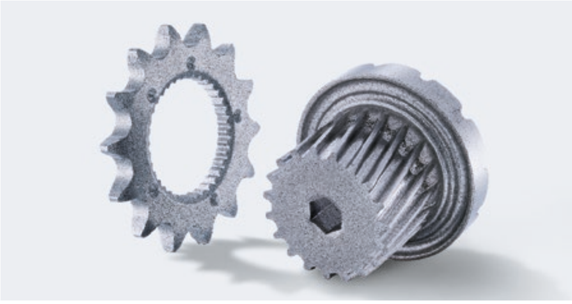


Process control – from manufacture of the powder metal to the sintered part

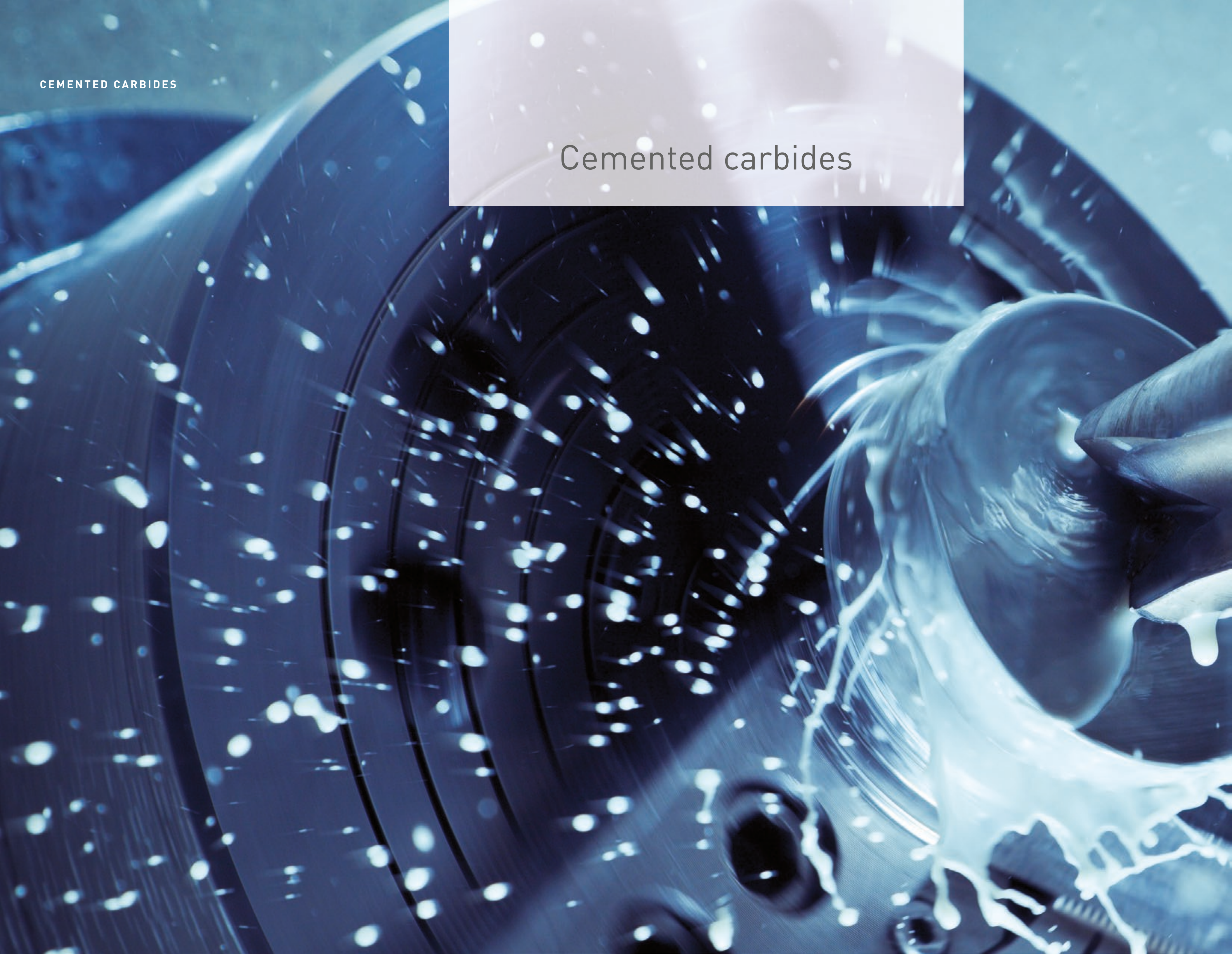
For over 70 years, FOERSTER has provided innovative solutions for non-destructive testing. Methods such as eddy current or magneto-inductive testing make the quality of raw materials, semi-finished products and components visible. And the ability to determine magnetic parameters provides customers with valuable information about the structure of the material as well as the mechanical properties that it imparts.

Producing components from powder metal has made enormous progress in recent years. In the meantime, levels of strength and wear resistance have been achieved that approach or even exceed the quality of conventionally manufactured parts. The process itself is tool-based, highly reproducible and resource-effective. The basic prerequisites are powders of consistently high quality and a stable manufacturing process.

FOERSTER test and measurement instruments provide you with the necessary parameters for process control. In addition, automation during parts handling, as well as the complete documentation of the results, round out a very efficient system.



Cemented carbides



Advanced demands require high-quality measurement

In many areas, cemented carbides are used for their toughness and hardness, as well as for their ability to resist both corrosion and heat. For example, on drill bits they are just as likely to be found in industrial material cutting and processing as in the surgical theater or the dentist's office.

In the hard metal producing industry, magnetic parameters are used for analyzing the material's microstructure. By measuring the coercive field strength on batch samples, it is possible to determine the grain size of the carbide quickly and non-destructively. This in turn provides inferences about the material's resistance and hardness. For this reason, one of the prerequisites for good quality management in powder metallurgy is the ability to determine the coercive field strength with precision.

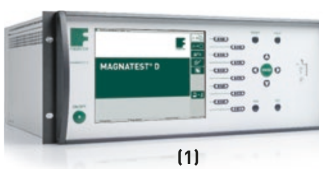
In cemented carbide manufacturing, it is important to ensure that the geometric arrangement of the binder phase is optimized for reproducible grain size. A simple, fast and non-destructive means of assessing the structure of carbides is by determining the magnetic saturation.

These parameters can be easily taken using the FOERSTER measuring instruments KOERZIMAT HCJ and KOERZIMAT MS.

Crack test for carbides

When powdered metal is pressed into blanks, it can lead to cracks and changes in the microstructure, which in turn can cause the parts to burst during the sintering process. But high-performance tools such as drill bits, milling machines or lathes require the very highest quality. For this reason, FOERSTER offers the test instruments STATOGRAPH and MAGNATEST; before the sintering process, they are used to examine the blanks for cracks and micro-structure flaws by means of eddy current. Volume reduction during the sintering process itself can also lead to cracks in the component – flaws that can be found and sorted out, again using eddy current.

(1) MAGNATEST® D
(2) STATOGRAPH® CM+
(3) KOERZIMAT® 1.097 MS

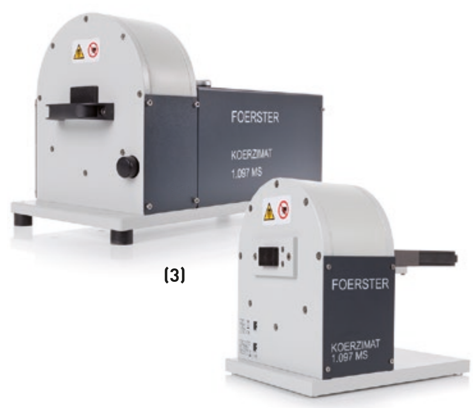


(1)

(2)

Powder test / raw material test

Even during preparation of the powder mixture, which consists of non-magnetic carbides and magnetic binders, determining the magnetic saturation (MS) provides an essential parameter for characterization of the raw material. The KOERZIMAT MS is used to test the magnetic saturation.



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Determination of the carbon balance

Cutting tools must be able to withstand high loads. An assessment of the carbon balance after sintering provides an important quality parameter for this. When under-carburization occurs in the sintering process, the resulting 'eta' phase can make the tool brittle, leading to breakage. In the case of over-carburization, the carbon precipitates out, which can result in insufficient strength and wear-resistance and, again, tool breakage.

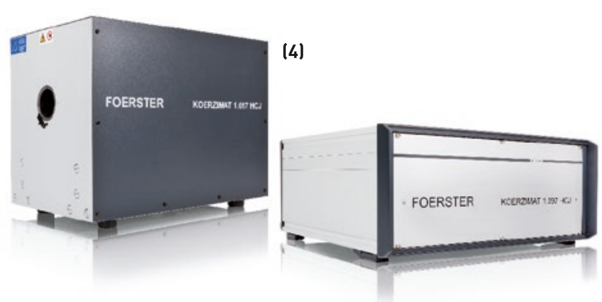
For this reason, the KOERZIMAT MS measuring system monitors the carbon balance by comparing the actual magnetic saturation (MS) with the nominal value.

Process monitoring during the sintering process
Material manufacturers often classify carbides by grain size. This parameter serves as an indicator of hardness as well as of flexural and compressive strength. Monitoring the sintering process involves comparing the grain size before sintering and afterwards. There is a correlation between the grain size and the parameter 'coercive field strength' (H_{cJ}). The fineness of the bifurcation in the binder phase – and thus the coercive field strength – goes up with increasing grain fineness in the carbide phase and decreasing binder-metal content. The quantity of binder metal left over can be characterized by the magnetic saturation (MS).

With the KOERZIMAT measuring system, both coercive field strength and magnetic saturation can be determined quickly, precisely and independently of shape in order to optimize the sintering process.

Density measurement / condition monitoring
Especially brittle materials must be completely free of defects, such as pores that reduce the material density. It is therefore important to know whether the material has been sintered to the density that is, at least in theory, achievable. For this, one takes the coercive field strength H_{cJ}. This parameter approaches a maximum that depends on the temperature and duration of the sintering. If the coercive field strength is too low, the density will also be less than the nominal value, indicating e.g. incomplete density sintering. For quality assurance, the KOERZIMAT HCJ measurement system can determine and monitor the coercivity on batch samples.

(4) KOERZIMAT® 1.097 HCJ



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Components

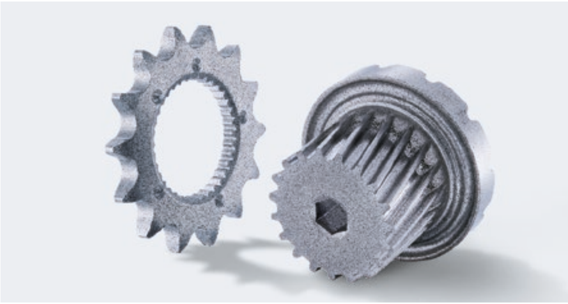
Quality monitoring of sintering processes for high-value components

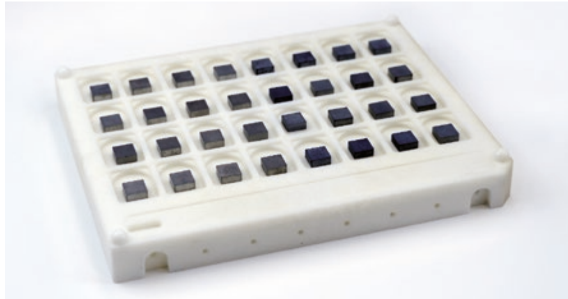
Complex components are manufactured ever more frequently by sintering. In mass production, this represents an economical alternative to conventional metal casting. High-quality metal powders, minutely accurate molds and a precisely controlled sintering process are prerequisite for fabricating mechanically robust components of perfect quality: These are used in the automotive sector and many other industrial applications.

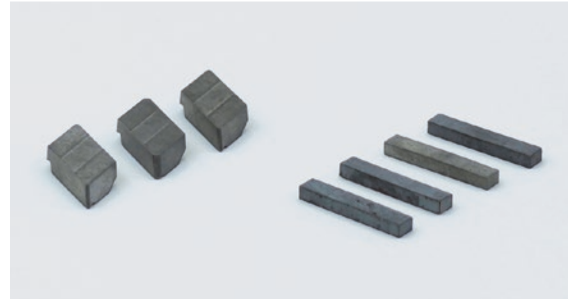
FOERSTER test and measurement instruments help to verify the quality of the raw powder, as well as to monitor the pressing of the green compacts and the actual sintering process.

Tested components include:

- Fasteners
- Housing parts
- Transmission parts
- Drives
- Actuators







FE sintered parts

For cost reasons, complex-shaped parts are often manufactured using the sintering process. These include magnetically soft components such as housings and fasteners, as well as mechanically stressed parts in the area of drives and motors. The raw material quality of the FE powder, as well as the size and uniform distribution of the grains before and after the sintering process, are factors that determine such mechanical properties as strength and wear resistance in the manufactured component. These parameters correlate with the measured quantity of coercive field strength. The KOERZIMAT can be used to monitor the entire production process from assessment of the powder quality to evaluation of the sintering process.

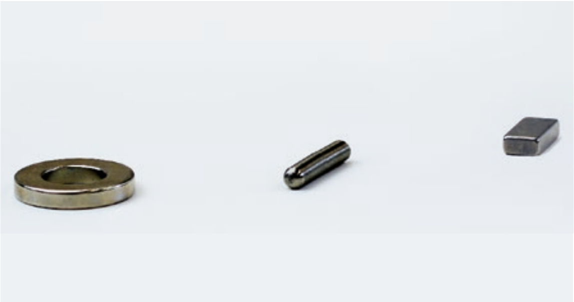
Green compacts

It is possible to achieve excellent material densities without porosities already in the prefabrication step of isostatic pressing. The KOERZIMAT measuring system can obtain information on particle size distribution and density even at this early product stage. These are essential parameters for controlling the production process.

MIM parts

Metal injection molding is a cost-effective alternative for manufacturing high-quality metal components by combining injection molding with subsequent sintering. Also for this method, the coercive field strength can be used to assess the quality of both the raw powder and the bond achieved by the sintering.

(1) KOERZIMAT® 1.097 MS
(2) KOERZIMAT® 1.097 HCJ



AlNiCo magnets

A cost-effective manufacturing process for AlNiCo magnets also involves the pressing and sintering of appropriate metal powders. The quality of the raw powder, as well as the structure created during sintering – consisting of a non-magnetic metal grid with magnetizable CoFe inclusions – can be evaluated using the KOERZIMAT. Here again, correlations to the coercive field strength and magnetic saturation are used for assessment.

Testing of coin blanks

Coins pass through many hands and have to withstand quite a lot over their service life. It is therefore important that the blanks are sintered correctly. Key parameters for monitoring the sintering quality are material density and surface quality. In this case, the mobile test device SIGMATEST takes indirect density measurements via electrical conductivity. If the sintering quality is good, the electrical conductivity will be relatively high. The high frequencies involved can also be used to monitor the surface porosity on random samples.

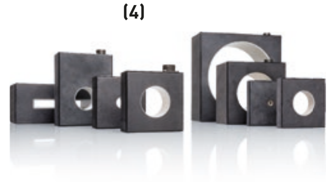
Testing the microstructure of complex mass-produced components

Complex mass-produced components are fabricated at high production speeds. Nevertheless, it is important to check whether all the sintering process steps, such as compacting and calibration, have been carried out correctly. With the MAGNATEST D, the parts can be checked directly in the running production line in a 100% series test. For this purpose, the parts pass through an encircling coil that induces eddy currents in the material. In case of material mix-ups or faulty sintering processes, the resulting test voltage will differ significantly from the reference parts. Defective components are thereby detected and automatically sorted out.

(3) SIGMATEST®
(4) Encircling coils
(5) MAGNATEST® D

(3)

(4)



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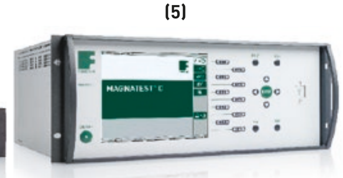
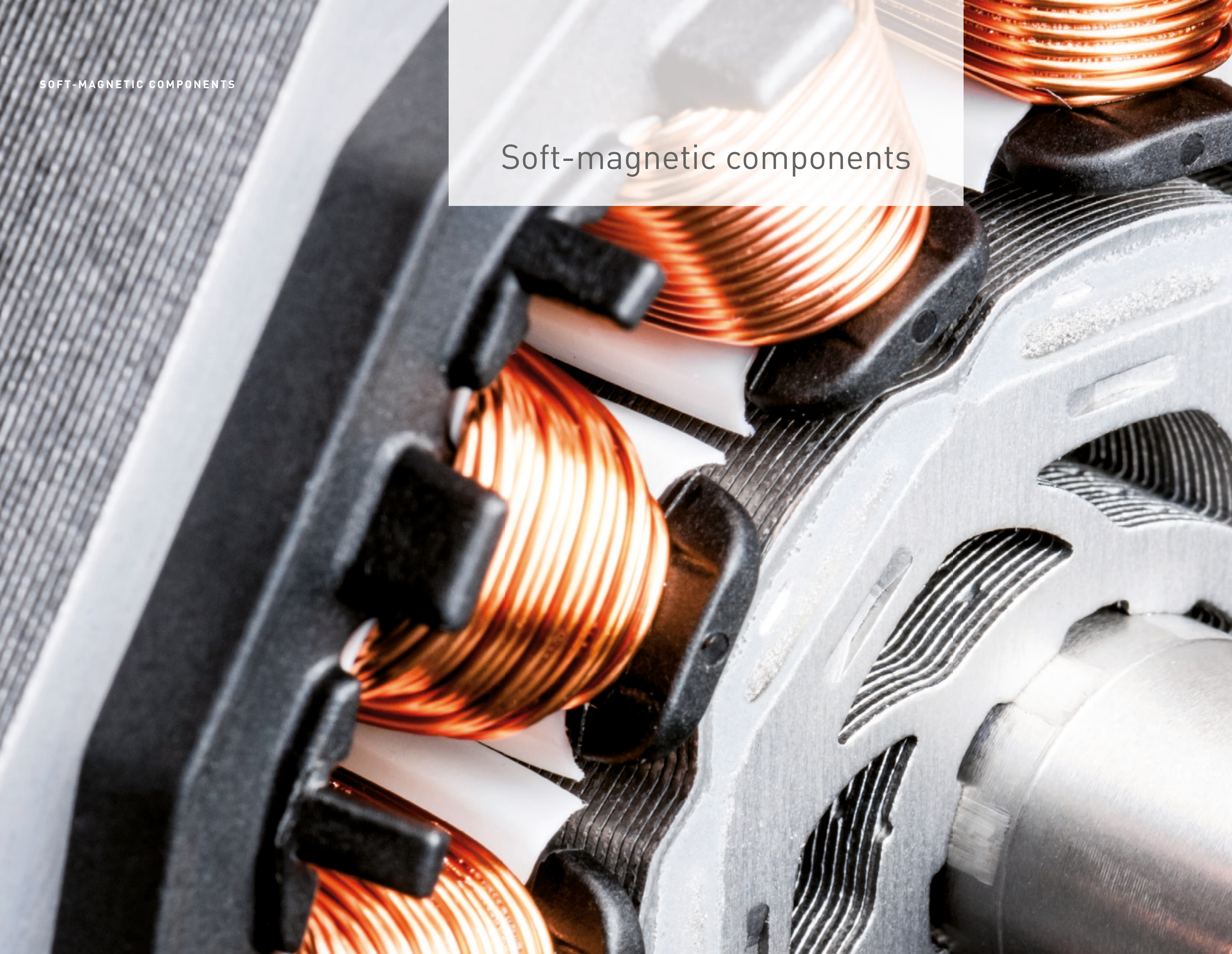


Soft-magnetic components



Increasing demand for soft-magnetic components

Magnetically soft components made from metal powders are required in many different applications. Their largest area of application is in the automotive industry, especially in electric motors and actuators. The reasons for this are many.

Manufacturing soft-magnetic components from powder metal allows for the production of complicated shapes that would be impossible using conventional methods. In contrast to hard metals, magnetically soft components can be easily magnetized by an external magnetic field and then demagnetized as needed. This enables the conversion of electrical signals into motion (actuators) or motion into electrical signals (sensors) by applying a magnetic field.

Soft magnetic composite (SMC) materials are used in electric motors, as they are particularly well suited for high-frequency applications. Their material structure results in lower eddy current and anomalous losses, thus significantly increasing the efficiency of the electric motor. With the KOERZIMAT HCJ and KOERZIMAT MS measuring systems, the magnetic properties of soft-magnetic components can be monitored – before, during and after the manufacturing process.

Qualification of raw material

The electromagnetic properties of the raw materials are decisive for the performance of the electroagnetic actuator made from them. In order to qualify a material's suitability for such purposes, the KOERZIMAT determines key magnetic characteristics. Testing is carried out either directly during production of the raw material or during incoming goods inspection before further processing. In this way, the quality of the materials can be continuously monitored and documented.

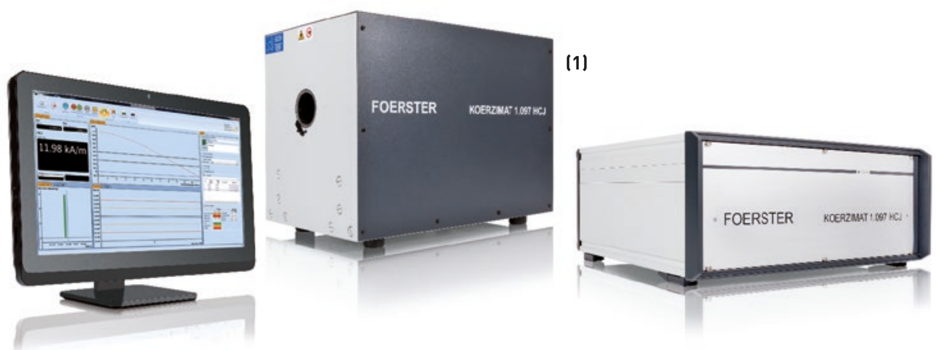
Process monitoring in component production

During the production of soft-magnetic components for electromagnetic actuators, the mechanical finishing processes – smoothing, grinding, polishing and machining, etc. – all contribute to an accumulation of internal mechanical material stresses. These cause a loss in the electromagnetic power, which correlates with the magnetic material property of coercive field strength.

The original condition of the material can be restored through heat treatment. The coercive field strength is therefore measured with the KOERZIMAT HCJ before and after final annealing, in order to monitor the material properties in the production process and, if necessary, to trigger corrective action.

With the KOERZIMAT MS, the weight-specific magnetic polarization can also be measured, which allows conclusions to be drawn about the material's density (quality of the pressing). Both measuring systems can also be used for green compacts and powders.

(1) KOERZIMAT® 1.097 HCJ



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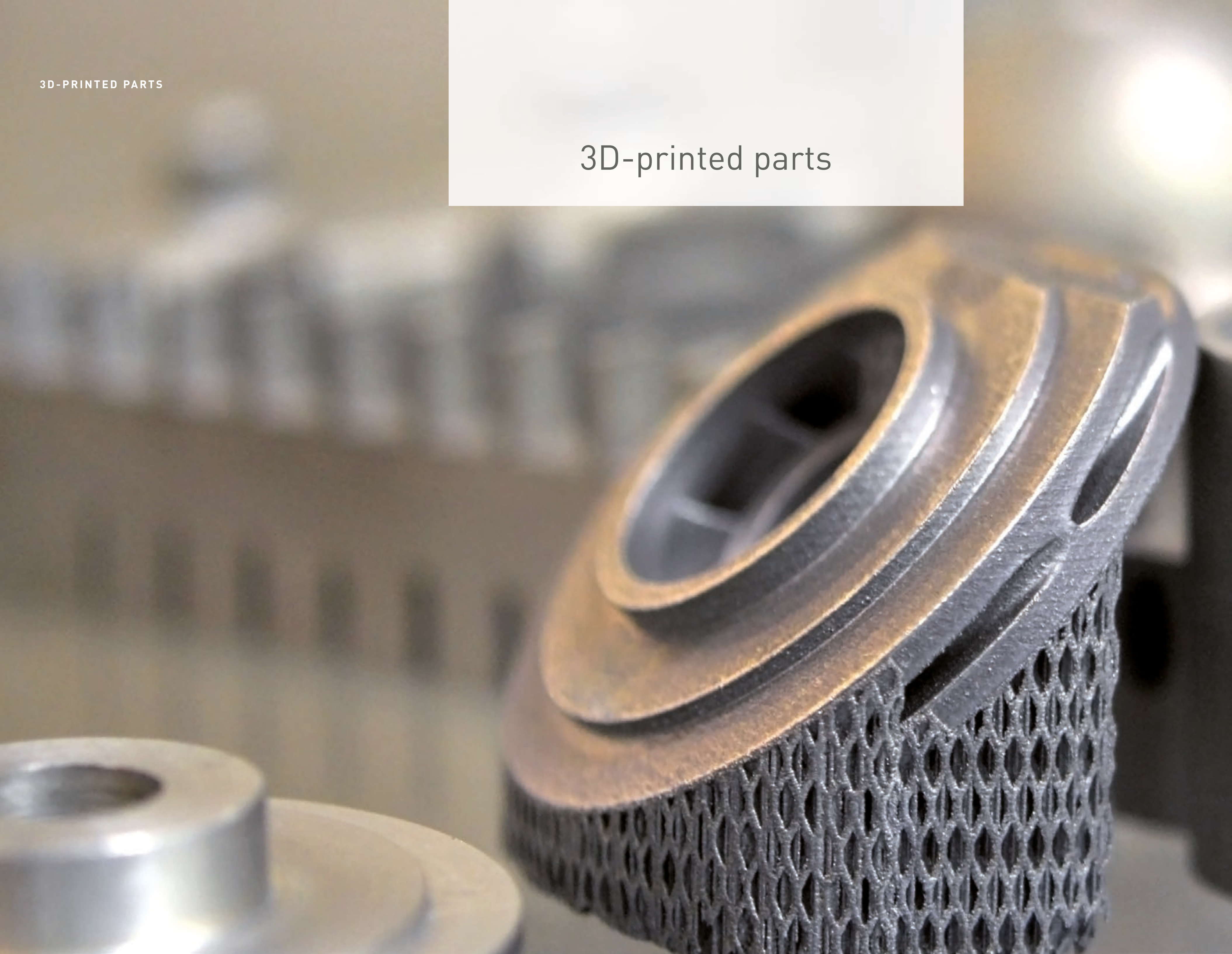
Cylinder liners / crankcases

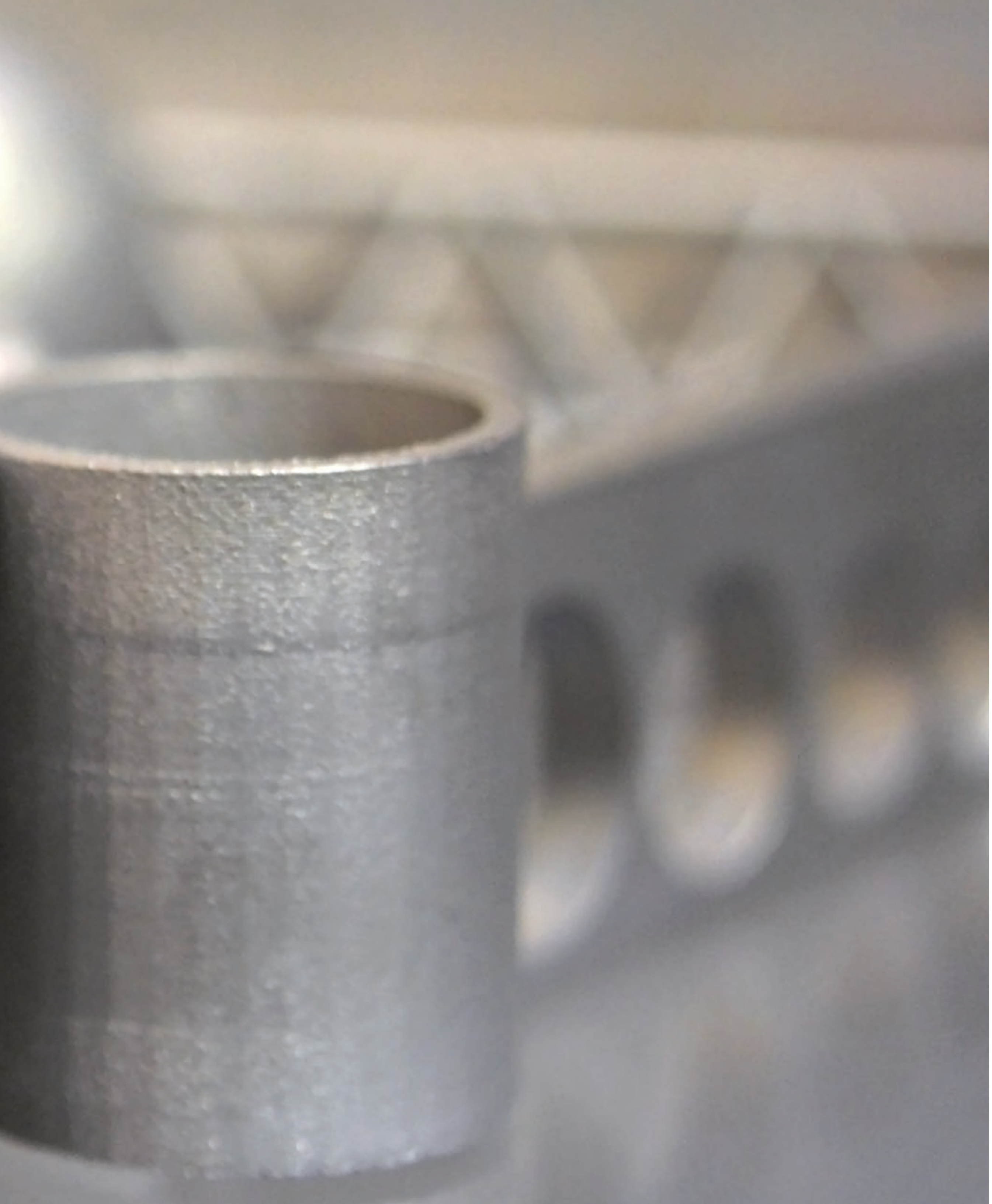
Soft magnetic composites (SMCs) are mainly used for high-frequency applications to make optimum use of energy resources. The KOERZIMAT HCJ employs the coercive field strength to monitor the quality of such process steps as annealing, mechanical processing or casting in plastic for SMCs.

On the other hand, the KOERZIMAT MS measuring system enables determination of the saturation magnetization – and thus the proportion of magnetizable material in the SMC. Both measurements are performed quickly, precisely and independently of sample shape. In addition, they can also be used for green compacts and powders.

(2) KOERZIMAT® 1.097 MS

3D-printed parts





Additive manufacturing for complex shapes

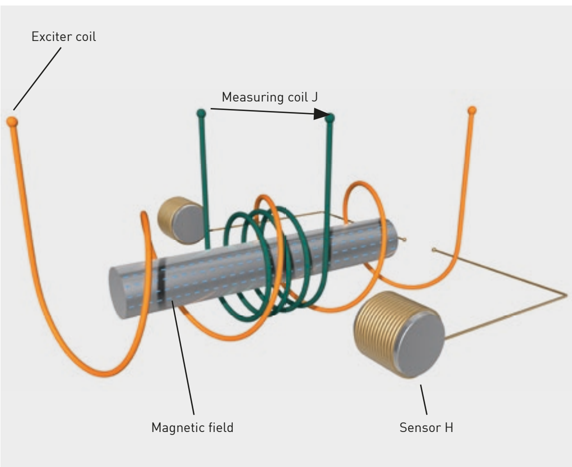
As industrial requirements on component shape grow, for example in the automotive and aerospace sectors, so does the importance of additive manufacturing – also in powder metallurgy. As a production technology, 3D processes are used to print complex-shaped components. Then, like in traditional manufacturing, the green parts are sintered at higher temperatures.

For monitoring this sintering process, FOERSTER offers the measuring systems KOERZIMAT HCJ and KOERZIMAT MS. Both devices enable the fast, precise and shape-independent determination of the coercive field strength and magnetic saturation, which are important test indicators for material quality.

(1) KOERZIMAT® 1.097 HCJ
(2) KOERZIMAT® 1.097 MS

J(H) hysteresis

The open magnetic circuit method provides a quick way to determine the total DC magnetic hysteresis of magnetically soft materials under industrial conditions. Using the precise J-coil, the raw material from which the electromagnetic actuators (e.g. common-rail injection) are made is tested for key parameters. The H-sensors precisely determine the coercive field strength H_{cJ} of the finished magnetically soft components and carbide materials.

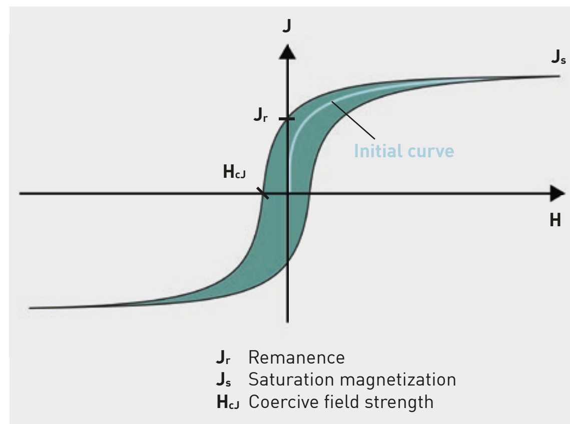


The principle behind determining magnetic properties

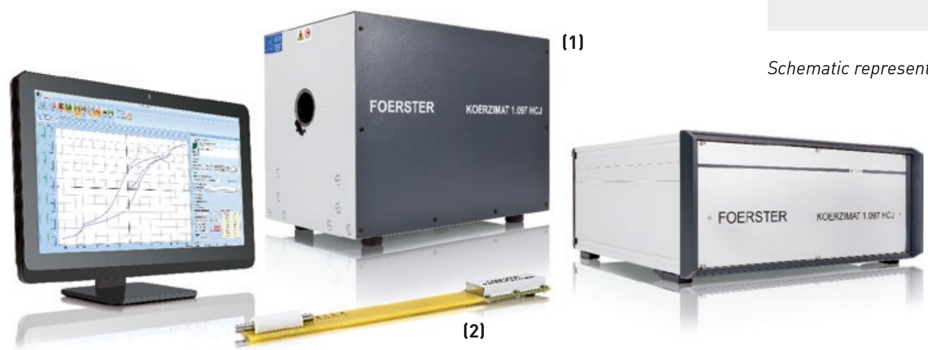
The total J(H) hysteresis represents the resulting energy losses (remagnetization losses) of the components during operation of the actuators. Here, the coercive field strength H_{cJ} is also an important indicator. The relative permeability μ_r (slope of the initial curve) characterizes a dynamic behavior of the components in the magnetic circuit: The higher the relative permeability μ_r, the faster the magnetization of the components in the electromagnetic system – which increases the system's dynamics.

During the manufacture of magnetically soft components, mechanical processes such as machining, finishing, grinding and polishing, as well as heat treatment (final annealing), can greatly alter the magnetic parameters mentioned above. Because some of these magnetic properties must be retained through the component state, the parameters J(H), μ_r and H_{cJ} should be monitored – a task for which the KOERZIMAT measuring system is ideal. Since J(H) and μ_r can only be determined for standardized samples (e.g. rings, round bars and sheet metal strips), the parameter H_{cJ} is of particular importance when testing sintered parts. This also enables the testing of complex shapes.

In the carbides industry, the coercive field strength H_{cJ} is used for analysis of the microstructure (grain size and distribution uniformity, proportion of binder metal) as well as for monitoring the manufacturing process (sintering).



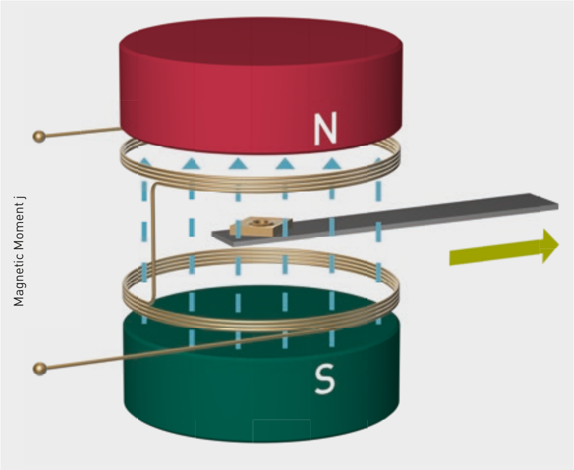
Schematic representation of the J(H) hysteresis



(1) KOERZIMAT® 1.097 HCJ
(2) J sensor

Weight- and volume-specific saturation polarizations

The KOERZIMAT MS system is an excellent option for fast, shape-independent measuring of the magnetic saturation polarization and/or the dipole moment of a material in an industrial setting.



The principle behind determining the magnetic saturation polarization

Via a special configuration of the permanent magnets (Halbach Array), the sample is magnetized to saturation such that no electrical resources are required for magnetization. When the sample is pulled out of the magnet, the magnetic dipole moment is determined by means of two coils (Helmholtz coil) and a fluxmeter.

In powder metallurgy, the weight- and volume-specific saturation polarizations are important indicators during the material manufacturing process. If the weight or density of the material is known, the KOERZIMAT software automatically calculates these two material parameters. Once the measured values are compared with the material constants for cobalt or nickel, the KOERZIMAT MS software assesses the magnetic binder content.

Microstructure as seen under the scanning electron microscope

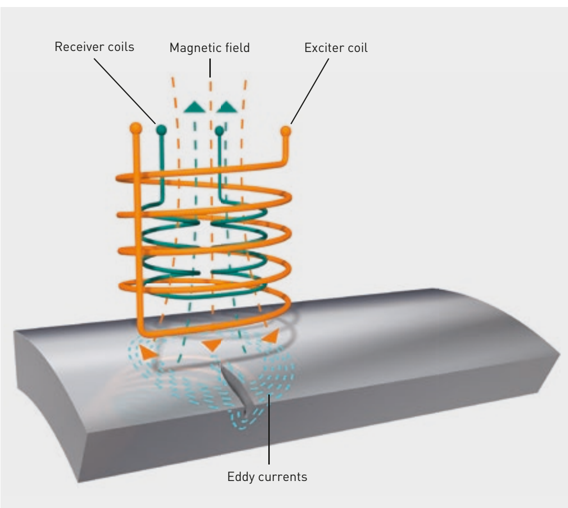
(3) KOERZIMAT® 1.097 MS

(3)

Surface crack testing

Non-destructive testing using the eddy current method

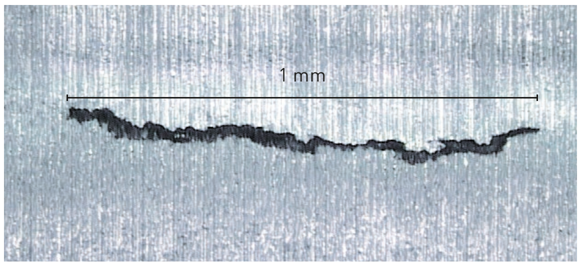
The keen attention paid to quality these days – not to mention the risks associated with product liability – increasingly necessitates 100% inspections of components. The eddy current method according to DIN EN ISO 15549 is a non-destructive and non-contact method for material testing. It detects surface defects such as cracks, overrolling, pores or cavities – and it works quickly, reliably and economically. Using differential measuring coils, a magnetic field is generated that induces high-frequency eddy currents in the material. The receiver signal is evaluated against the amplitude and phase shift relative to the exciter signal, exposing even the smallest defects in the material.



The principle behind eddy current testing

Testing for cracks in the material

For crack detection, the test specimen is either mechanically rotated and scanned by a fixed probe, or a rotating probe scans the stationary sample. As long as there is no damage in the material, the eddy currents flow through evenly, because the electrical resistance is homogeneous. But should there be a crack somewhere, the eddy current density is different from that of an undamaged part. This change is recorded and displayed as an error signal.



Natural cracks in turned surfaces

Testing with the STATOGRAPH®

Eddy current testing for material cracks requires evaluation electronics and probes that are adapted to the testing task. Depending on the test situation and sample, the STATOGRAPH family of instruments provides the right system for this purpose.

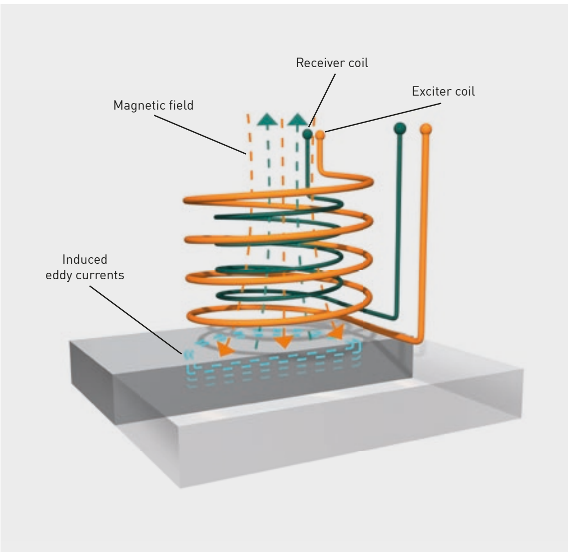
Many standard and shape-matched probes for special applications are available. The choice of probe depends on the shape of the component, the cycle time and the error specification.

(1) STATOGRAPH® CM
(2) STATOGRAPH® CM+
(3) Probes
(4) FLEXPROBES

Material and microstructure testing

Magneto-inductive method

The magneto-inductive method also relies on eddy current, because its wide frequency range allows it to be used for different testing purposes. While testing with high-frequencies reveals material cracks, low-frequency magnetic-inductive testing enables greater penetration depths and thus provides information about the sample's tempering. Material and/or microstructure tests can be employed to prevent material mix-ups or to identify incorrectly tempered parts. Typical sorting criteria include alloy content, surface hardness, hardness depth, strength and microstructure.



The principle behind magneto-inductive testing

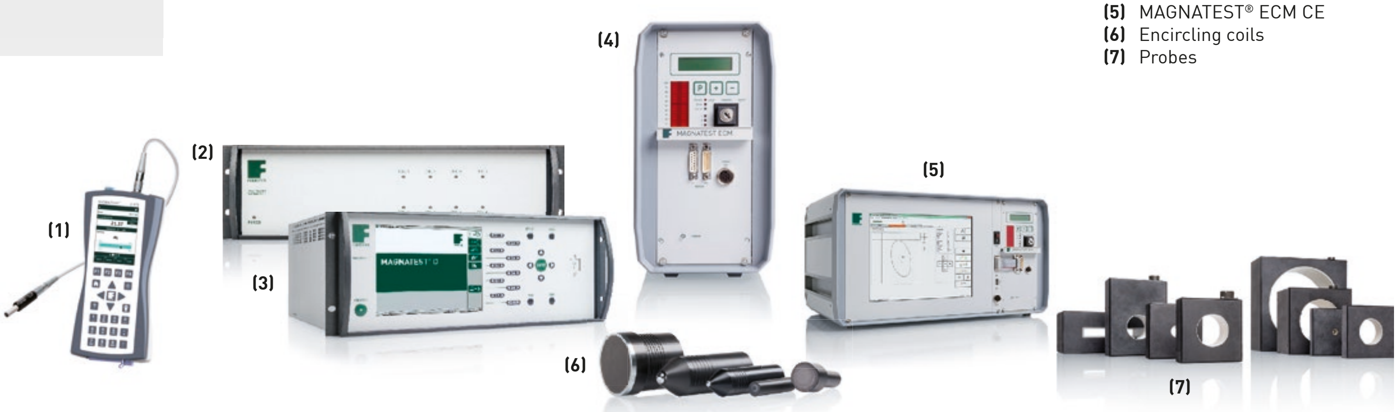
Testing for material properties

To test for material properties, the samples are generally passed through an encircling test coil, where low-frequency eddy currents are induced into the material. The test voltage recorded by the sensor is a result of the sample's magnetic and electrical properties; the voltage value is graphically displayed as the measuring point. The various hardness states, alloy constituents or microstructure conditions exert an impact on the receiver currents, thus allowing conclusions to be drawn about the material properties of the test specimen.

The MAGNATEST® series

Depending on the application and sample, the MAGNATEST series provides the right system for magneto-inductive microstructure and material testing of metallic components. A variety of coils and probes round off the extensive product portfolio.

(1) SIGMATEST®
(2) MULTIPLEXER MAGNATEST® D
(3) MAGNATEST® D
(4) MAGNATEST® ECM
(5) MAGNATEST® ECM CE
(6) Encircling coils
(7) Probes



Your system provider for fully automated measuring and testing systems

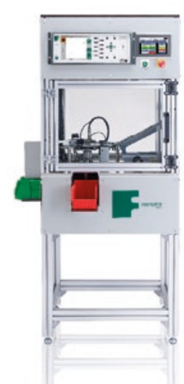
Automation solutions from FOERSTER

Making components from metal powder is done in mass production, and it involves a complex sequence of different manufacturing processes. To guarantee smooth production and still ensure thorough quality control, we have tailored our offerings to your needs.

We therefore provide not only individual measuring/test instruments but also fully automated systems that include all the machinery for your production. These are developed and manufactured in close cooperation with you, our customer – and always with your applications and requirements in mind.

After consultation with our product and sales specialists, we develop a concept for fulfilling your objectives. During the subsequent execution process, we enter into product-specific cooperation with professional mechanical engineers to ensure that you get the best possible solution. We also work with suppliers named by you, the customer – providers who may already know the details of your component and have direct experience with it. After fabricating a system, we continue to support you during its commissioning; plus, our service team is always there for you afterwards if you have any questions. In addition, we offer individual product and service training, so you can make the best use of your system – starting on day one.

Fully automated test system with automatic loading of the sample buffer



FOERSTER tester for automated microstructure testing on various small components

FOERSTER

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