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MECHATRONIC PRODUCTS – FROM DEVELOPMENT INTO VOLUME PRODUCTION

DR. WOLFGANG GUTH

Rotation Speed measurement, ABS, Multipol Encoder, Hall effect- and Magneto-Resistive sensors

1 Introduction

Integrating several functions into a single component is the key to providing modern economical solutions not only in the car industry but also in industry in general. In order to provide solutions to such complex problems, minimise development times, bring innovative products into series production quickly and in a customer orientated and process-friendly manner all at the same time, interdisciplinary solutions are an absolute necessity. At Freudenberg Dichtungs- und Schwingungstechnik innovative products are the result of concentrated and effective project work carried out in a team-orientated development structure. This strategy ensures that our new solutions are tailor-made to suit our customer's needs. A perfect example of such a solution is the development of the Simmerring with magnetic encoder function.

Advancements in Anti-lock Braking (ABS) Systems, engine control – and gearbox management systems are leading to growing requirements in speed-measurement and rotation angle detection, and to significant leaps in sensing technology, system sensitivity, accuracy and signal handling. Further technological advancements of the automotive industry, such as traction control and dynamic stability systems (ESP,DSC), antirollback features, brake assistance and navigation systems are based on the high signal quality of wheel speed measurement.

Speed-sensing systems are found on many rotating components in vehicles. Engine applications include crankshaft speed and camshaft position measurement, as dictated by engine control management .

One of the most important fields of speed detection is found in ABS, where speed is translated to acceleration and used to control braking force to avoid locking of wheels. In advanced ABS, speed is used to control vehicle traction and stability, by accounting for forces and acceleration. In these, accurate speed detection on each wheel is absolutely important.

2 Background

Passive Encoder / Passive, Inductive Sensors

Traditional solutions used for wheels speed detection were based on a combination of e.g. toothed wheels or slotted metallic tone-wheels which were used in conjunction with passive, inductive sensors. The sensor incorporates a permanent magnet, which is the source of the magnetic field. Both components required a relatively large space (Figure 1) .

The airgap between the encoder and the sensor had been limited to some tenths of a millimetre. The analogue signals of those inductive sensors are strongly dependent on the measured wheel speed. Low speeds produce weak signals and ultimately there is a minimum speed of 4 km/h that can be detected.

Passive Encoder / Active Sensors (Hall- or Magneto-Resistive)

Hall-effect and Magneto-Resistive sensors, so called " active" sensors involve semiconductor technology with a digital signal output and all advantages of digital signal processing.

The development of the active sensors enabled a space reduction in the metallic tone wheel. Some applications already demonstrated an integration of the tone-wheel in the bearing seal. Small, strong and expensive rare earth magnets have been used up till today as an integral part of the active sensors. The airgap between the encoder and the sensor can be widened up to 1.5 mm.

Active Encoder / Active Sensor

By using a multipolar magnetised elastomeric tone-wheel as an encoder in combination with Hall or Magneto-Resistive sensors a full active speed measurement is achieved. Alterning north and south poles in the rubber layer of the encoder are stimulating the sensor, providing a non-biased, alterning flux and generating a digital speed independent output signal.

Advantages:

- Integration in the seal of the wheel bearing
- Compact design- less of weight
- Extended readable air gaps
- No permanent magnet in the sensor
- Identification of angle and direction of rotation
- "zero speed " detection

Hub Unit With Active Encoder / Active Sensor

Figure 2 shows a hub unit with the bearing integrating the sealing and encoding function. This solution is based on the described technology and state of the art for all new vehicles with ABS. The wheel speed signal can be used for:

- ABS-System
- ESP / DSC
- Navigation-System
- Brake assistant

3 The shortest possible route between the idea and the finished product

The solution to this problem is a radial shaft sealing ring which doubles as a signal emitter. However, the only way of achieving this is by integrating a carefully scaled signal emitting system into the seal itself. In order to transform this idea into a finished product as quickly and as consistently as possible, Freudenberg Dichtungs- und Schwingungstechnik made good use of the group's internal synergy to bring together an interdisciplinary team of specialists in electronics, materials, design, process and automation. The team was given the task of developing the product and advancing its industrialisation simultaneously, organised in two project teams

Development process

The factors which influenced the development of this product are highly complex. Specific operation conditions, handling-, shipping and assembling requirements define the main development fields. Internal specifications were derived and customer specifications included in a sophisticated development procedure. All this resulted in a comprehensive testing program which covered the following aspects: material specifications, mechanical functions, magnetic release, corrosion, bonding tests, temperature resistance, media resistance, fields of magnetic disturbance and ageing.

Controlling the manufacturing process

By installing the product development team and industrialisation team in the same area excellent information exchange, a good feed back is guaranteed and superfluous work and duplication is avoided

Robust manufacturing and quality assurance conditions for mass production are taken into account from early days of product development. The definition of the preproducts, the standardisation of the tools and production machines and the installation of the production line was the result of their work.

4 Competencies for the development of multipole encoders

Material development

The longstanding development experience of the sealing materials is a significant prerequisite in the success of the development of magnetisable elastomers.

Magnetic NBR and ACM materials are each optimised for special applications e.g. Media resistance for special bearing grease, temperature resistance up to 150° C, tensile strength more than 6 Mpa and elongation at break over 200 % allow a complex usage.

Only through the optimisation of the elastomer and magnetic characteristics can one achieve a stable and exactly controlled vulcanisation process as well as optimum mechanical precision and a fundamental factor for the encoding function.

Product design

Shorter development time requires more modern methods such as Nonlinear Finite Element Methods for structural mechanics, process technology and electromagnetic field calculation. In Figure 3 are shown simulations for optimisation of the magnetising tools and the assembling process. A proper heat dissipation during the magnetising process could be achieved as well as an optimised material flow in the mould.

Production

The production of encoders or bimaterial seals out of magnetised elastomers requires a new and much costlier process compared to the well known standard radial shaft seal production.

Already at the vulcanisation stage the fundamental quality level with regard to high magnetic precision has been established. This is vital because the random distribution of the magnetic filler is an important factor in magnetic precision.

Magnetisation- and measuring- process

Next to the material and process development the use of high precision magnetisation and measuring processes is also a very important factor.

The encoding function is 100 % checked and controlled during and after production. The customer is ensured guaranteed quality for reliable product function in sensitive ABS brake systems.

The close co-operation of Freudenberg engineers together with their partner at sensor- and ABS-manufacturers promotes deeper level of awareness in the total system of sealing-bearing-sensor and ABS.

Assembly and environmental influences

The overall function of the total system is influenced by the constancy of the airgap between the two components:

- assembly position
- axial- and radial run out
- thermal deforming
- dynamic stress

are determined and specified.

It is important to be aware of influence of pollution through ferrite particles as well as external magnetic field.

Through detailed field test together with our customers we are monitoring the usability under various field conditions.

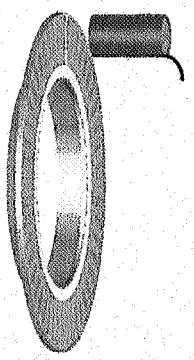
5 Summary

Active, multipol magnetic encoders have been introduced as an alternative to metal tone-wheels in rotational speed-measurement systems. Combined with new active sensors, magnetic encoders allow numerous advantages in performance and packaging. Measurable speeds, accuracy and digital signal processing are part of the growing requirements of wheel-speed sensing. Reduction in size and weight of both sensor and encoder, allowable air-gaps and wider positioning tolerances – provide major advantages in manufacture and assembly of e.g. ABS systems. Furthermore, since encoders may be combined with seals, at shaft-ends or in bearings, into a single component – a reduction in the number of parts is also achieved.

Magnetic encoder technology has matured to a stage of practical application. Production and testing processes have been optimised to ensure that performance and quality expectations are met. They are used in the automotive industry world-wide, have proved superior in performance and durability and are proving invaluable in active speed-measurement systems, as technology requirements increase.

Dr. Wolfgang Guth
Freudenberg Dichtungs- und Schwingungstechnik KG
Lead Center Simmerringe/Sensorik
D-69465 Weinheim
Germany
Phone: +49(0)6201/80-4985
Fax:+49(0)6201/88-3296
E-mail:wolfgang.guth@freudenberg.de

6 Figures

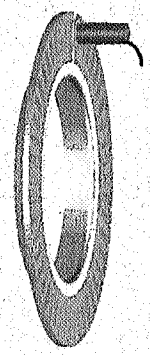


Encoder

- **passive**
- stamped parts with high precision

Sensor

- **passive**
- inductive principle
- analog signal

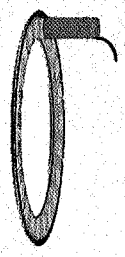


Encoder

- **passive**
- Integration in seals based on compact constructions
- reduced dimensions

Sensor

- **active**
- smaller magnet
- reduced dimensions
- digital signal



Encoder

- **active**
- alternating magnet field
- very small dimensions

Sensor

- **active**
- no magnet necessary
- good value
- digital signal

Bigger Air-Gap, Zero-Speed Detection
Possibility of High Integration

Figure 1: Development steps of Rotation Speed Detecting Systems

Fundamental need for each anti-lock braking system is the precise measurement of speed at each wheel.

The integration of impulse transmission into the wheel bearing seal in combination with active sensors makes it possibel to register driving speed right down to zero.

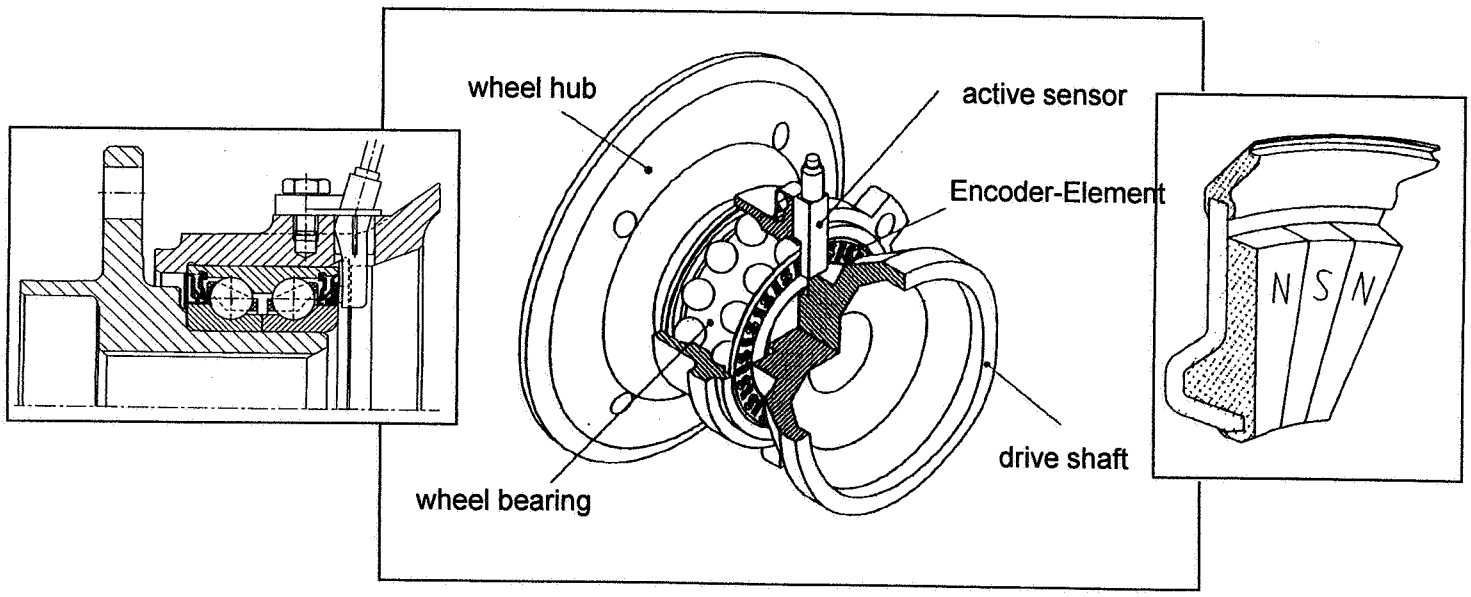


Figure 2: Hub Unit with Active Encoder Seal and Active Sensor

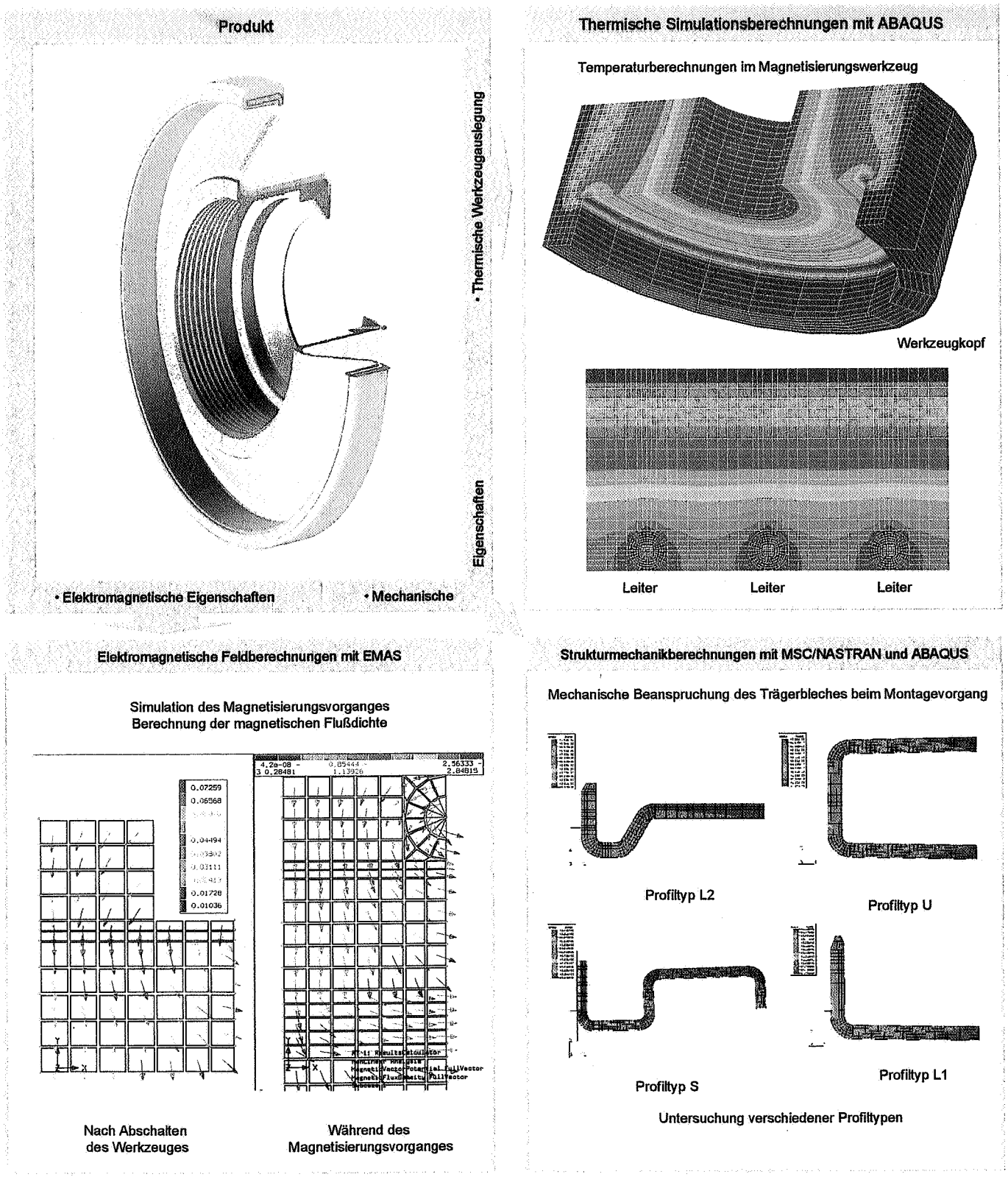
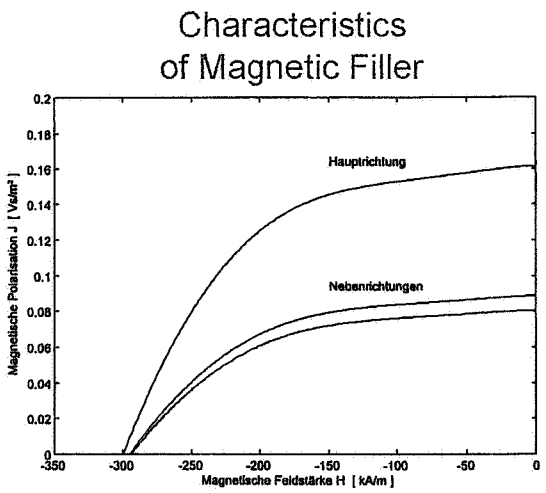
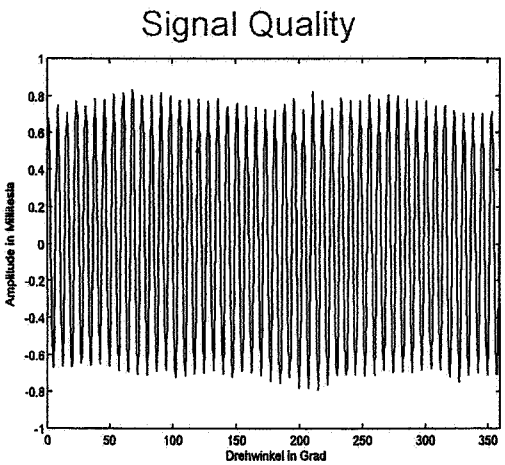
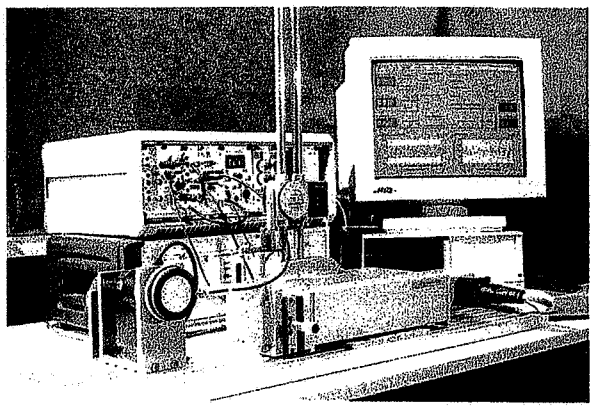
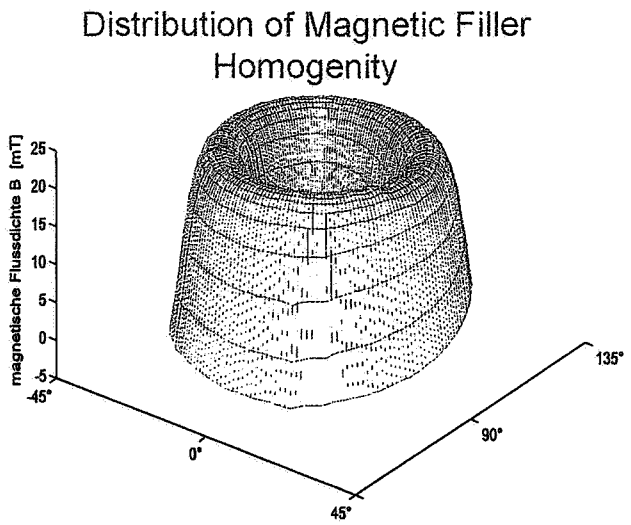


Figure 3: Product and Tool Design by Numerical Methods









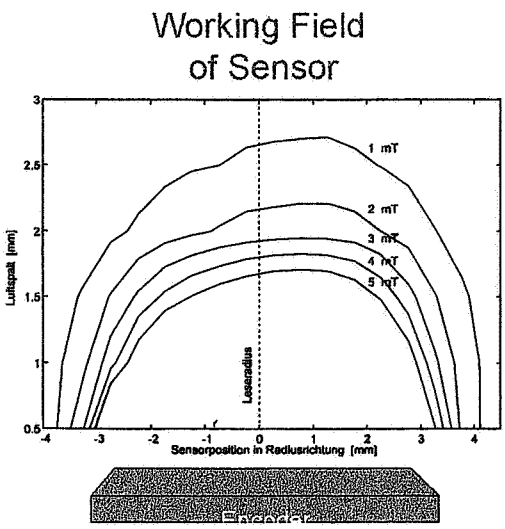


Figure 4: Measurement of Magnetic Characteristics