ADAPTIVE ON-LINE ADJUSTMENT
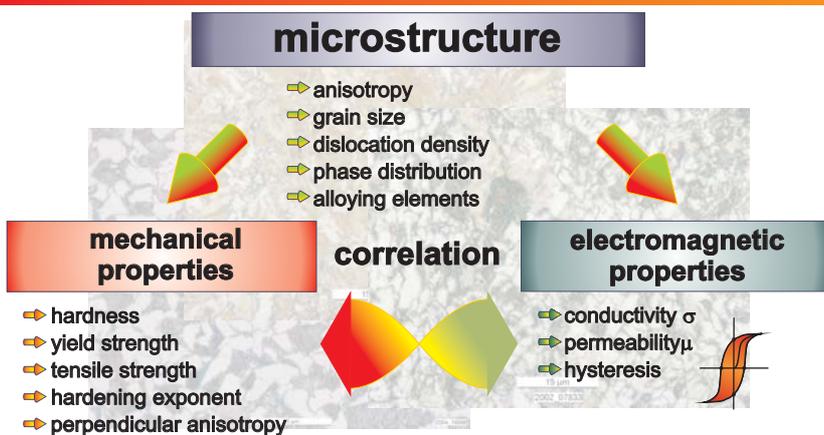## 3R ADAPTIVE QUALITY CONTROL (3R AQC)

3R-AQC is a fully automatic system for non-destructive testing of material properties and their interconnection with the machine settings. It is possible to compensate variations of the material properties from supplier to supplier, from batch to batch, from coil to coil and in a single coil, and thus to deliver constantly high quality, which is almost independent from material properties. Down time and rejections can be reduced to a minimum and so production costs can be lowered. When recording the material properties, the values from the eddy-current system are directly linked to the machine settings.

The system consists of a measuring coil, an eddy-current device, a computer and interface for the analog and digital in- and outputs. In the figure a system for spring production is shown. 3R-AQC measures the mechanical properties of the material by means of the eddy-current values, which represent the electromagnetic material properties and calculates the optimal machine settings for the current material properties.
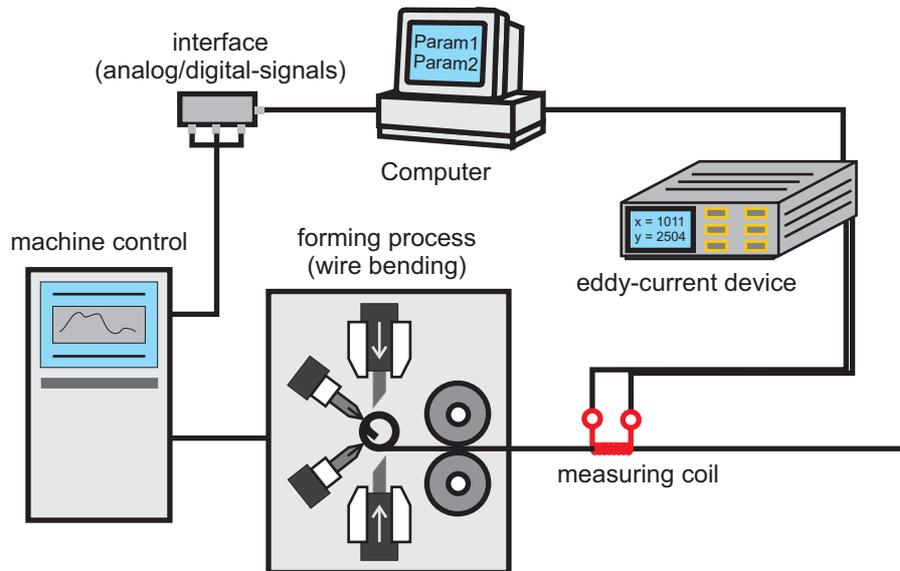
The system can be applied whenever the variations of the raw materials properties affect the quality of the process and the product. The process has to have at least one degree of freedom (one adjustment possibility) to compensate these variations and to adapt the process to the material properties. Application examples are bending of wire, bars, sheet metal, metal strips, tubes and profiles, rotary swaging of full and hollow material, rolling of gearings and other profiles, thread rolling etc. Besides the mechanical material properties the influence of the surface condition and the geometry are also detected. With the multi-frequent eddy-current measurement more information is acquired than by a tensile test, a bulge test or a miyauchi test. The material properties which are relevant for the specific forming process are automatically determined. So you change from the classical material properties to the operation specific reformability.
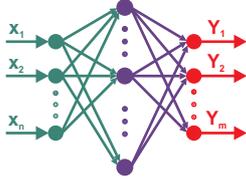

microstructure
⇒ anisotropy
⇒ grain size
⇒ dislocation density
⇒ phase distribution
⇒ alloying elements

mechanical properties
⇨ hardness
⇨ yield strength
⇨ tensile strength
⇨ hardening exponent
⇨ perpendicular anisotropy

correlation

electromagnetic properties
⇨ conductivity σ
⇨ permeability μ
⇨ hysteresis

The microstructural properties (anisotropy, gain size,...) affect the mechanical (hardness, yield strength, ...) as well as the electromagnetic properties. The electromagnetic properties can be measured with high accuracy by the eddy-current system and linked to the corresponding machine settings by an appropriate mathematical model.

This system is not limited to forming processes only. It can also be adapted to other manufacturing processes e.g. heat treatment, metal-cutting manufacturing, etc. Therefore, the electromagnetic properties of the raw material have to correlate with the properties affecting the production process, which in turn must be influenceable themselve. A major advantage of this system is the fact, that the measurement of the material properties takes place before the production process.

With the mathematical model the interrelations between the measured values and the resulting characteristic of the quality criteion of the finished part are known. So the machine settings can be adjusted to the effective measured material properties, which lead to a minimum of rejections and smaller tolerances of the treated quality criterion.

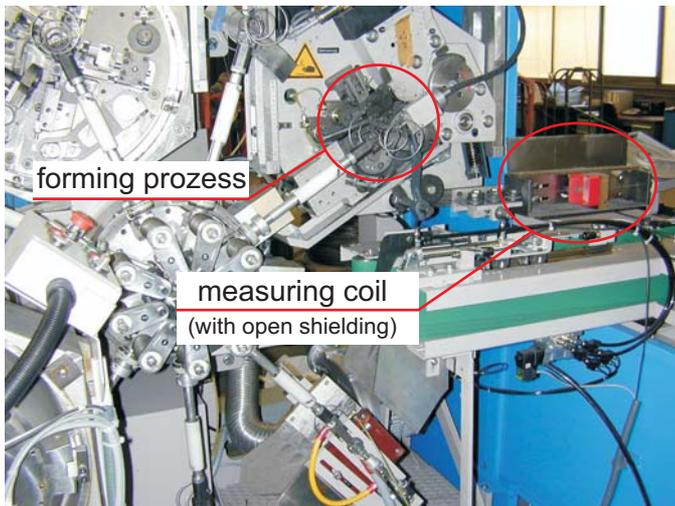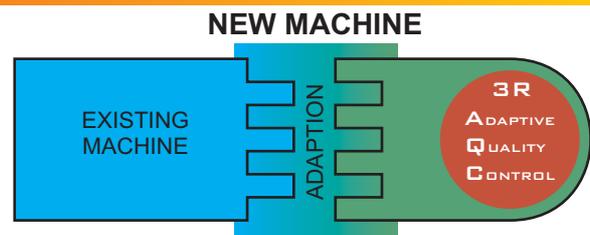**Neural network**

Multiple regression
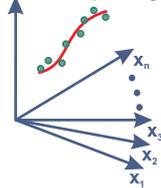
In the measurement computer, the output signals of the eddy-current device are linked to the microstructure and thereby to the effective material properties by an appropriate mathematical model. Possible methods are multiple regression algorithms, neural networks, genetic algorithms,.....

In order to unburden the staff as much as possible and to minimise the human factor in machine handling major attention was paid to the automation of the system functions:

- Automatic identification of the measuring parameters - only the best frequencies are used
- Automatic definition of the model structure - the optimal mathematical model is used
- Automatic determination of model coefficients - the model parameters are optimised
- Automatic training - the training process runs autonomous and needs no monitoring
- Adaptive control of the training set - data which falsify the model are separated out

3R-AQC is not limited to wires as raw material and bending as forming process. This system can also be applied in processes in which bars, tubes, metal strips and sheet metal are manufactured through deep drawing, punching, stamping, and so on. It is also possible to use the system in heat treatment or even metal-cutting manufacturing.

„3R Adaptive Quality Control" is an open system. It is not necessary to redevelop the system for each forming process, it just has to be adapted to the specific process and the specific machine. In that way a new machine generation can be developed in a very short time.

NEW MACHINE

EXISTING MACHINE

ADAPTION

3R **A**daptive **Q**uality **C**ontrol

forming prozess

measuring coil
(with open shielding)

The adaptive adjustment is already applied in practise, e.g. in wire bending for bed-spring production. Partner in this project was Spühl AG in St.Gallen, the leading manufacturer of machines for bed-spring production. It is a three dimensional bending process with several adjustment parameters. The bed-springs feature 14 quality and geometry characteristics at a production rate of 100 springs per minute. Relatively small variations of the mechanical properties of the processed wire already strongly affect its reformability and thus the geometry and the quality of the springs. Deviations of the geometry cause problems for the grasper and during assembly.

Some of the objectives for an application of 3R-TQC are:

- drastic drop of rejections
- smaller tolerances of the quality characteristics of the product
- minimise reworking, changeover time and start-up procedures
- massive reduction of complaints and credit items
- avoidance of 100% monitoring of finished products
- developing of new market segments